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INTENSITY CONTROL OF FLASHERS

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JUNE 1972

FINAL REPORT

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16. Abstract

This report describes tests and experimentation with intensity control of condenser discharge lights (flashers) with a three-step intensity control, and used in a Runway Alignment Indicator Light (RAIL) System as part of a Medium Intensity Approach Light System with sequenced flashers (MALSR) during both day and night and over a wide range of visibility conditions. Also, test and experimentation were conducted with a voltage sensing circuit intended to operate the intensity controlled MALSR from the Control Tower using current changes in the runway lighting circuit. Two intensity controlled MALSR systems; one, 2,400 feet long on Runway 4, and another, 3,000 feet long on Runway 13 were flight tested during the evaluation. The results of the evaluation tests indicated the following: (1) the voltage sensing circuit using current changes in the runway lighting circuit provided satisfactory operation of the MALSR from the Control Tower, (2) the intensity controlled MALSR operated satisfactorily and adequately supported flight operations during both day and night and over a wide range of visibility conditions, (3) compatible intensity levels between the MALSR and the runway lights were obtained to provide a satisfactory intensity balance for flight operations during the weather conditions flown, and (4) the operation of condenser discharge lights during night VFR and IFR conditions were not distracting and did not subject pilots to annoying glare.

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PREFACE

The author acknowledges the contributions made to the project by NAFEC personnel in the Flight Operations Branch, the Photographic Section, the Engineering Support Section, the Meterology Laboratory, the Electric Shop, the Landing Section, the Human Engineering Branch and his associates in the Airport Section. To project pilot, Irving Budoff, appreciation is particularly expressed for his assistance in the flight test program.

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INTRODUCTION

Purpose

The purpose of this evaluation was to devise a suitable method of varying the intensity output of condenser discharge strobe lights (flashers) to eliminate distracting flasher glare during the hours of darkness; to design intensity levels of sequenced flashers used with Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights (MALSR); to provide a satisfactory intensity balance with the runway lights for operations during day and night visual flight rules (VFR) and instrument flight rules (IFR); and to design and test a satisfactory method of operating the MALSR from the Control Tower using changes in current in the runway lighting circuit.

Background

In early 1970, the Federal Aviation Administration's (FAA) Systems Research and Development Service (SRDS) requested the National Aviation Facilities Experimental Center (NAFEC) to develop a feasible method for controlling flasher intensity of condenser discharge lights in order to eliminate distracting glare during the hours of darkness. This was in response to several complaints concerning flasher glare from the Runway Alignment Indicator Lights (RAIL) portion of the MALSR that resulted in delays in commissioning several new MALSR installations.

The MALSR system (Figure 1) design limited the Medium Intensity Approach Light (MALS) to two intensities, 100 percent and 10 percent, and the RAIL to one intensity, 100 percent at all times. This combination of intensities made the flashers overly bright and unsuitable for night VFR operations and the system was not compatible with the brightness steps of the runway lights. NAFEC was requested to design and modify the flashers with three-step intensity control in order that the MALSR with three-step brightness control could operate with intensity levels comparable with those of the runway lights. In addition, NAFEC was requested to design and test a circuit for achieving manual and automatic control of the three-step intensity controlled MALSR from the runway edge light circuit.

Previous project work in Final Report NA-69-7 (RD-69-8), "Test and Evaluate RAIL for Approach Guidance," Project No. 430-209-03X, investigated flasher glare reduction using glare shields and voltage control. Those methods were unsatisfactory and in this effort intensity control was accomplished by varying the value of the flash discharge capacitor.

DISCUSSION

Equipment Description

Intensity Control Modification: Experiments with intensity control were made inhouse with condenser discharge light (flasher) units using the relationship between flashtube energy (power), capacitance, and voltage in the equation

$$W = C\bar{V}^2$$

where W = Watt/seconds W/s
C = capacitance in Microfarads (uF)
V = Voltage in Kilo Volts (kV)

Intensity control was obtained by changing the values of C in the equation which corresponds to C1, the flashtube capacitor, shown in Figure 2 of the simplified flasher circuit. Previous tests with intensity control conducted under Project 430-209-03X attempted to change flasher intensity by varying the supply voltage across the flashtube. This method was unsatisfactory as the limited range of intensity changes which resulted before flasher unstability occurred could not be detected by the eye. In the simplified circuit shown in Figure 3, several values of capacitors were substituted for C1 which resulted in intensity changes of 99 percent. The values of capacitors tested, their intensity distribution, and other photometric data are shown in Appendix A Figures 1-1 through 1-20. Life tests of the flasher unit were conducted using a 2 uF, 2,500 VDC condenser in place of the 30 uF, 2,500 VDC condenser normally used in the circuit, to determine the effects of capacitor changes on tube life and flasher output. The results of the tests after 500 hours of operation indicated that - (1) Tube life was extended past the nominal specified value of 500 hours, (2) Flasher operation was normal and remained stable for the average life of the tube specified for 500 hours or 3.5 million flashes, and, (3) Flasher output remained essentially the same during the test.

As a result of the tube life tests and the breadboard intensity control tests, it was decided to modify one flasher unit for 3-step brightness control. If operation proved feasible, flasher units type FAA-1106 would be modified to operate in a "RAIL" as part of a MALSR system. The modification shown in Appendix A, Figure 1-21, and photographs (Figures 4 and 5) required the addition of two capacitors and three relays to the existing circuit, the relocation of several components and the removal of discharge relay K103. The two capacitors and the switching relays provided the flasher unit with intensity outputs of 1 percent (150 cd) and 9 percent (1,300 cd) of the original intensity, for use during night VFR and night IFR

weather operations. The original effective intensity output of 15,000 cd would remain unchanged and would be used for day IFR operations. MALS intensities of 4 percent (260 cd), (step #3), 20 percent (1,300 cd), (step #4), and 100 percent (6,500 cd) (step #5), would be paired with intensities of 1 percent, 9 percent, and 100 percent on the MALSR system.

Preliminary intensity control tests conducted with one flasher unit indicated the necessity of a switching unit to operate the flasher circuitry in proper switching sequence to eliminate arcing and burning of relay contacts due to excess high voltage.

A control unit consisting of switch S2 and relays K4, K5, K6, and K7 shown in Appendix A, Figure 1-22, was designed to operate the MALSR on three-step brightness control. The unit used variable time delay relays to apply power and switch intensities to the flashers in the proper sequence. In the flasher circuit, before intensities can be changed, power must be removed from the unit and the flash-tube capacitor allowed to discharge to a safe level. Likewise, intensity selection must be made first before power is applied to the flasher from the "off" position.

Eight condenser discharge lights were modified for three-step brightness control for use as a "RAIL" in a 3,000 foot MALSR system installed on Runway 4 for flight tests to one-half mile visibility conditions. A waiver could not be obtained on Runway 4 to conduct flight testing below 1 mile. Subsequently, after sufficient 1-mile flight test data were collected on Runway 4, the RAIL system was relocated to Runway 13, combined with and reconfigured with an existing approach light system (ALS) into a 3,000 foot MALSR for flight operations to one-half mile visibility. Split intensity operation was used on the flashers in the 3,000 foot system for the medium intensity setting used for night IFR operations. Flashers at stations 16, 18, 20, and 22 had effective intensity outputs of 1,200 candelas and flashers at stations 24, 26, 28, and 30 had an effective intensity output of 4,000 candelas. A 2,400 foot MALSR for use at glide slope angles greater than 2.75°, (Handbook 6850.2) was installed on Runway 4 for flight operations to 1-mile visibility conditions. The RAIL system was 600 feet shorter than the 3,000 foot system and split intensities were not used for the flashers in the medium intensity setting. Outside of that, the 2,400 foot intensity controlled system was identical to the 3,000 foot intensity controlled system.

Voltage Sensing Circuit: A voltage sensing circuit consisting of a 6.6/6.6 ampere, 100-watt current isolating transformer, a variac, a stepdown transformer and a three-channel solid state logic circuit (Figures 6 and 7) was designed to operate the three-step intensity controlled MALSR using current changes in the runway lighting circuit.

Control of the MALSR was exercised from the control tower in the "automatic" mode of operation by changing the intensity setting of the Runway 4 detented brightness potentiometer from step 1 through step 5. In the "manual" mode, MALSR operation was controlled from the remote station, Building T-4 (Appendix A, Figure 1-22).

The logic circuit consisted of three solid state switching channels, whose function was to select and control MALSR intensity levels from changing voltage levels fed in from the series runway lighting circuit. Logic channel A, the low intensity channel, controlled relay X from a nominal current reading of 3.4 amperes corresponding to a 4V to 7V signal input. Logic channel B and relay Y, the medium intensity channel, controlled MALSR operation from a nominal current reading of 4.1 amperes corresponding to a 7V to 10V input signal. Logic channel C and relay Z, the high intensity channel, controlled MALSR operation from current readings of 5.2 amperes or a 10V to 13V input signal. Protective circuitry was included to insure operation on only one MALSR intensity channel at a time. After the sensing circuit was installed, erratic operation of the MALSR was experienced, due to misadjustment of the runway current regulator and excessive "play" in the brightness detented potentiometer caused by worn detents in the switch section. This condition was remedied by replacing the detented brightness potentiometer and by adjusting the current regulator for normal operation, according to the specifications listed in Advisory Circular AC 150/5345-10B, April 8, 1968.

The operation of the MALSR from the control tower, using the voltage sensing circuit, was successfully demonstrated to SRDS and NAFEC personnel during night VFR operation.

Flight Tests: Flight evaluation tests consisting of 66 approaches by 18 pilot subjects, using a wide variety of aircraft from Aerocommander to Convair 880, were conducted during day/night VFR/IFR visibility conditions. The purpose of the flight tests was to determine whether adequate guidance and identification was provided by the MALSR when it was operated at intensity levels preselected for compatibility with intensity levels of the runway lights for existing visibility conditions.

Two intensity controlled MALSR systems were flight tested. A 3,000 foot system on Runway 13 (located initially on Runway 4) and a 2,400 foot system on Runway 4. Approaches to Runway 13 used ILS for operations down to 1/2 mile visibilities: to Runway 4, VOR/DME was used for flight operations to 1 mile visibility conditions. MALSR and runway light intensities were operated in accordance with preselected values listed in Table 1. The high intensity settings were used for day IFR operations, the medium intensity settings were used for night IFR, and the low intensity settings for night VFR operations. Flight test data were provided from pilot questionnaires, (Figure 8) completed after each flight test. An analysis of the flight test data is located in Appendix B.

Test Results: For both day and night IFR operations, the 3,000 foot and 2,400 foot MALSR systems provided a satisfactory intensity balance with the runway edge lights and the intensities were considered adequate for the operations conducted. With the exception of height guidance (which is generally considered poor for any approach light system) the systems adequately identified the approach zone and enabled the pilots to maneuver as required to accomplish a successful instrument-to-visual transition and landing. The condenser discharge and steady burning lighting were considered to be verv important and useful in the operations conducted.

For night VFR operations, the intensity levels of both systems were adequate and a satisfactory intensity balance was obtained with the runway edge lights. Whereas, the systems were considered very important to IFR operations, pilots rated the systems as "nice to have" in VFR conditions.

When operating in visibility conditions below 1/2 mile (1/4 mile) the condenser discharge lights were visible for several seconds ahead of the steady burning lights. During one approach, this resulted in a pilot unintentionally banking the aircraft away from the approach light system: indicating a lack of roll guidance for sustained flight with the condenser discharge lights only.

CONCLUSIONS

Based on the results of the flight test evaluations and operational tests, it is concluded that:

1. Both the long (3,000 foot) and short (2,400 foot) MALSR systems will serve adequately in VFR weather conditions and in IFR weather conditions down to 1/2 mile visibility.

2. The long system will support operations on the lower ILS angles and the short system will support operations on the higher ILS angles.

3. The "flashers" as developed with three intensity controls can be configured, if required by unusually bright or dark environments, to prevent glare at night, or increase effectiveness at night, by making adjustments in either or both VFR or IFR settings used in the trials at NAFEC.

4. A voltage sensing circuit in the runway edge light system will provide satisfactory operations of the approach light system.

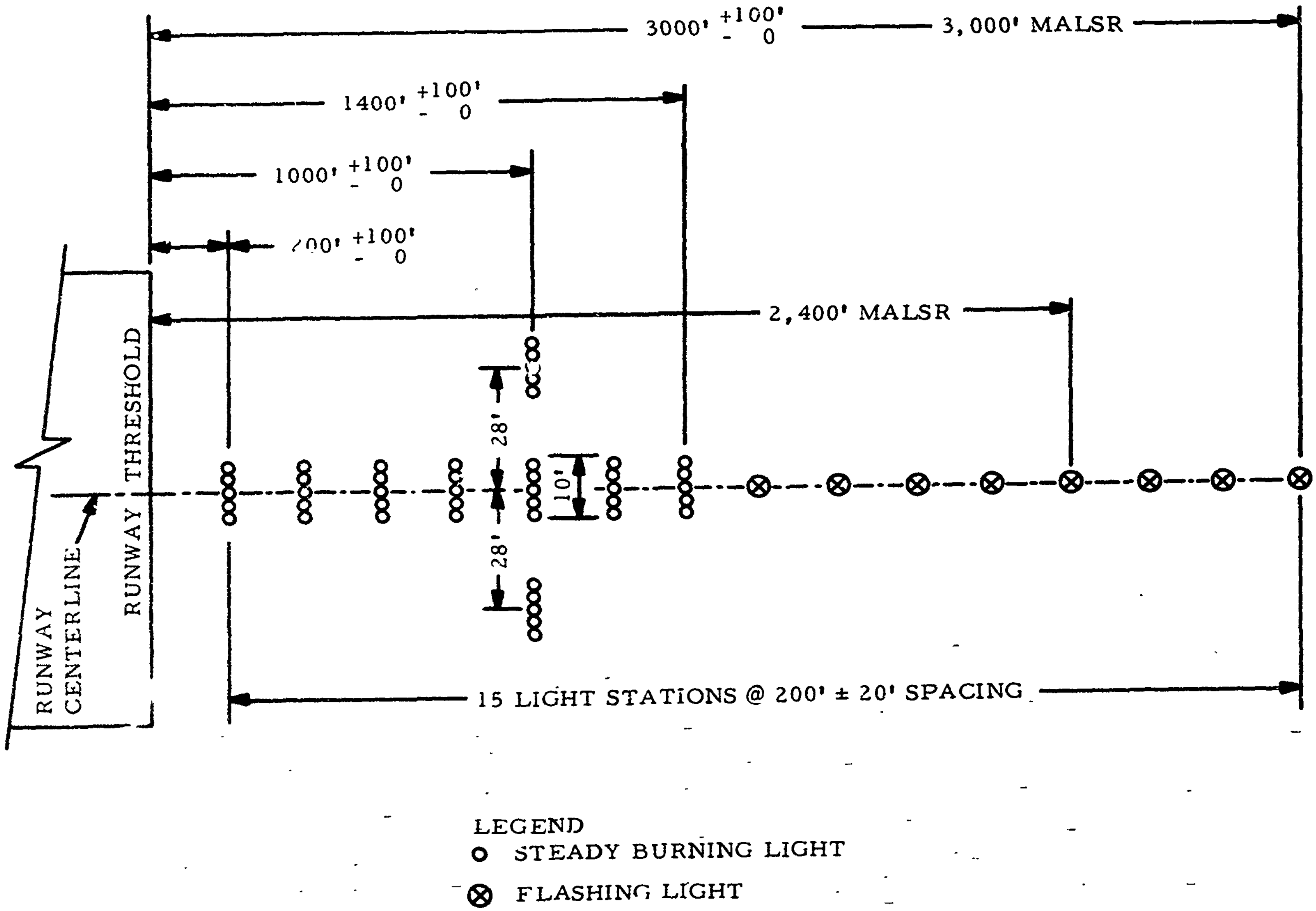
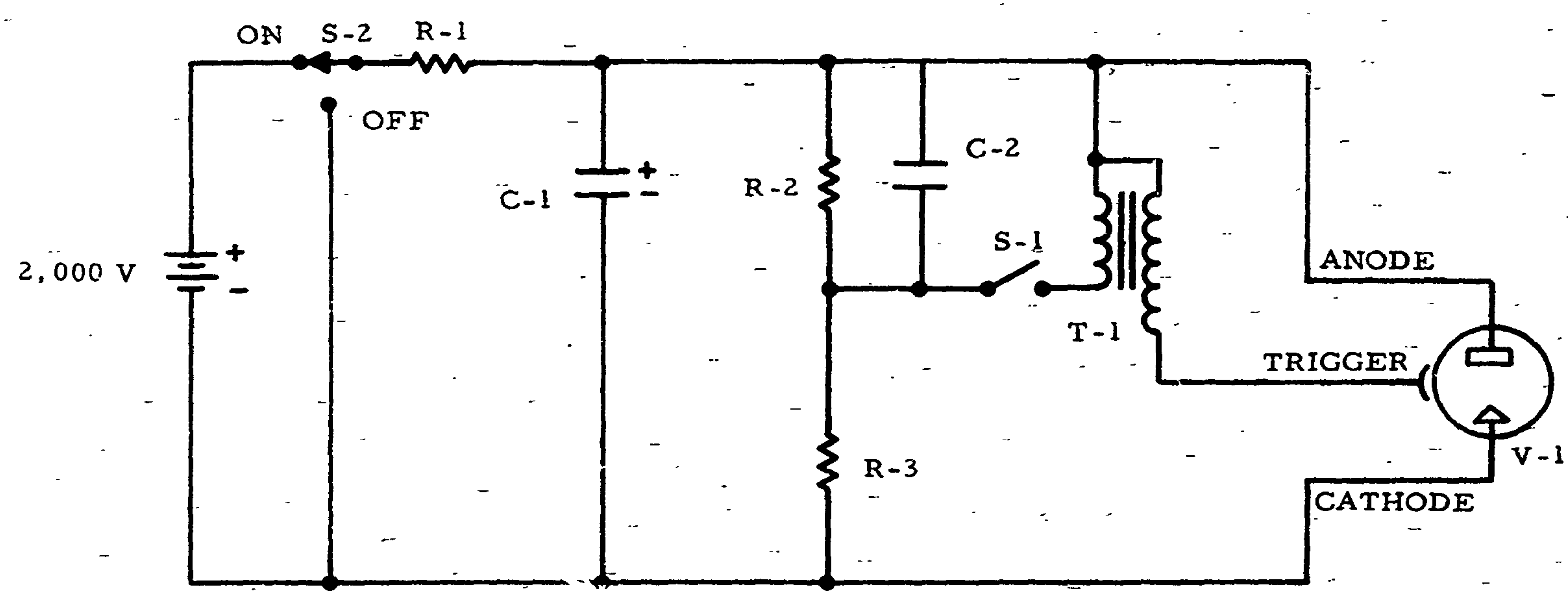


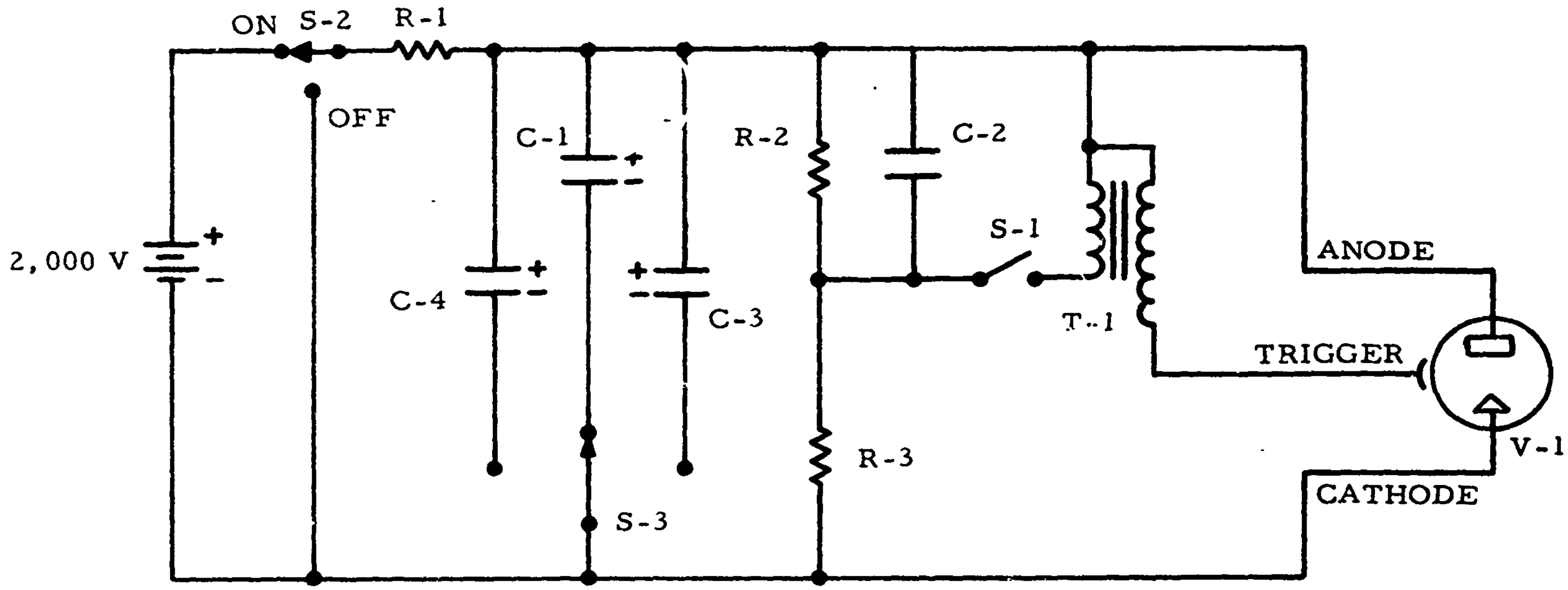
FIGURE 1 MALSR CONFIGURATIONS TESTED



C-1 = 30 μF, 2500 Vdc
C-2 = 1 μF, 600 Vdc
S-1 = TRIP SWITCH (MOTOR DRIVEN TO OPERATE 2 TIMES PER SECOND)
S-2 = ON/OFF SWITCH
T-1 = IGNITION COIL

R-1 = 500 OHM, 200 W
R-2 = SIX 220 K, 2 W RESISTORS IN SERIES
R-3 = 220 K, 2 W
V-1 = FLASH TUBE

FIGURE 2 SIMPLIFIED DIAGRAM, UNMODIFIED FLASHER CIRCUIT



C-1 = 30 μF, 2500 Vdc
C-2 = 1 μF, 600 Vdc
C-3 = 4 μF, 2500 Vdc/10 μF, 2500 Vdc
C-4 = 1 μF, 2500 Vdc
T-1 = IGNITION COIL
S-1 = TRIP SWITCH (MOTOR DRIVEN TO OPERATE 2 TIMES PER SECOND)
S-2 = ON/OFF SWITCH
S-3 = BRIGHTNESS INTENSITY SWITCH
R-1 = 500 OHM, 200 W
R-2 = SIX 220 K, 2 W RESISTORS IN SERIES
R-3 = 220 K, 2 W
V-1 = FLASH TUBE

FIGURE 3 FLASHER CIRCUIT MODIFIED FOR INTENSITY CONTROL

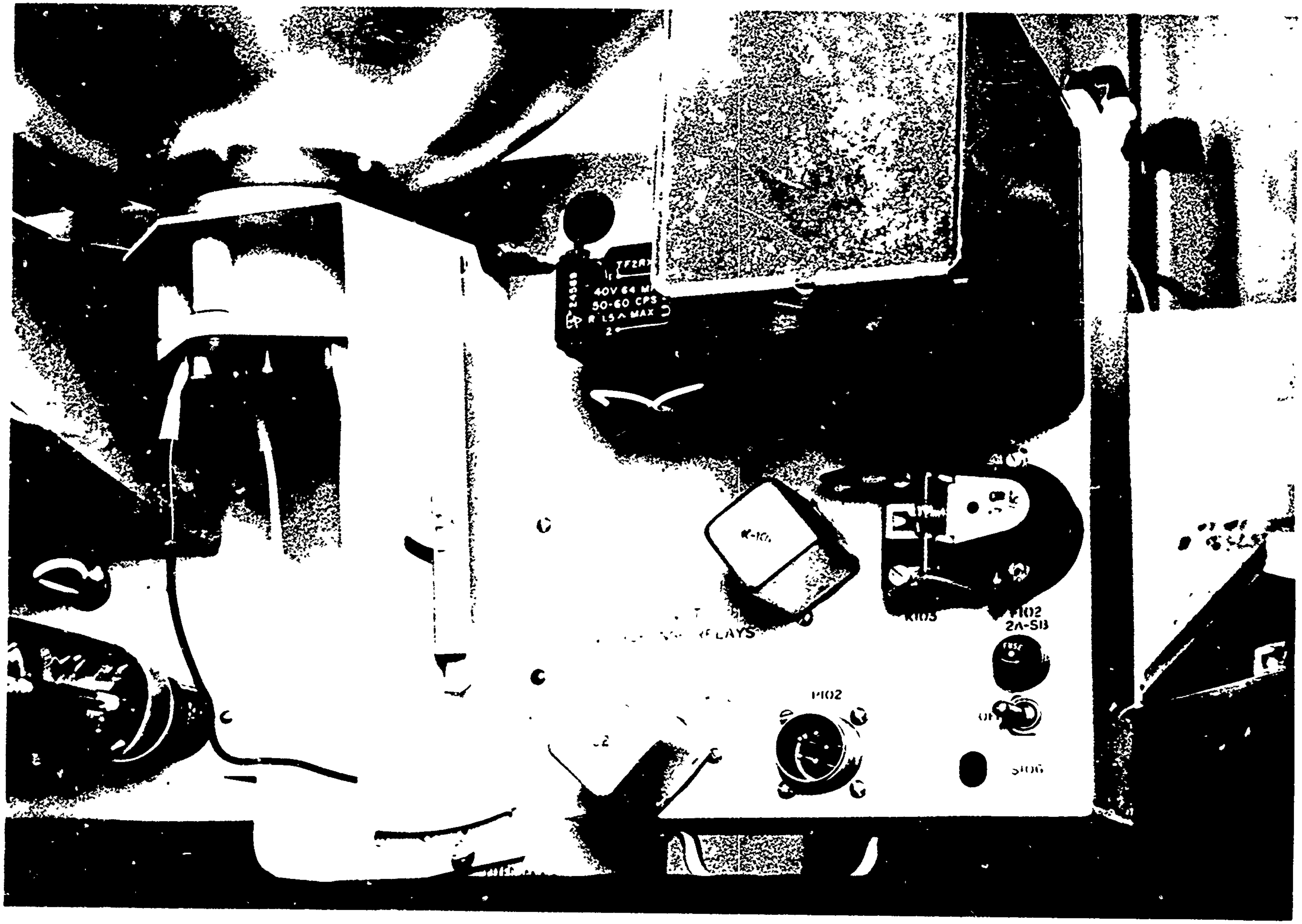


FIGURE 4 FLASHER UNIT TOP VIEW (UNMODIFIED)

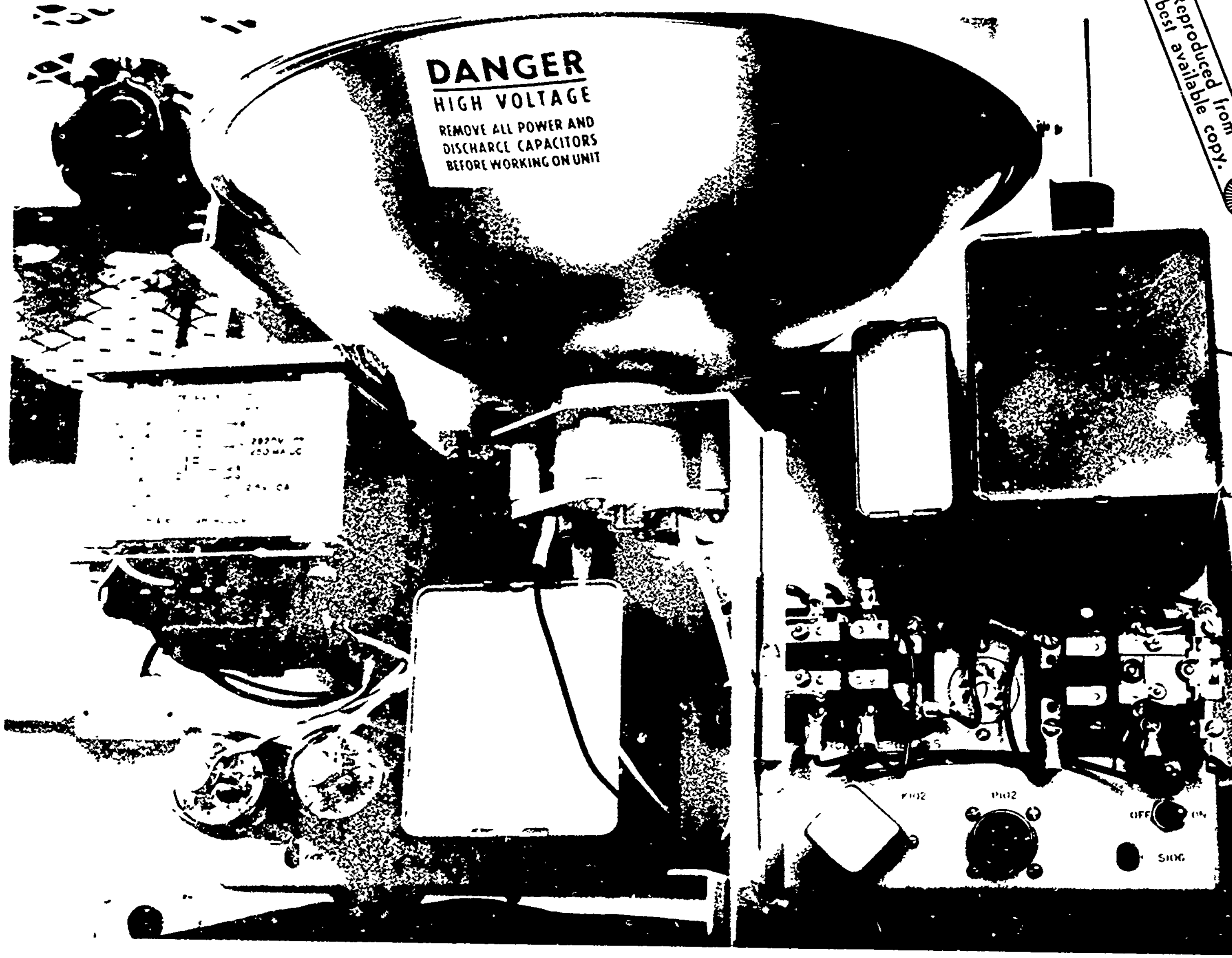


FIGURE 5 TOP VIEW OF MODIFIED FLASHER UNIT

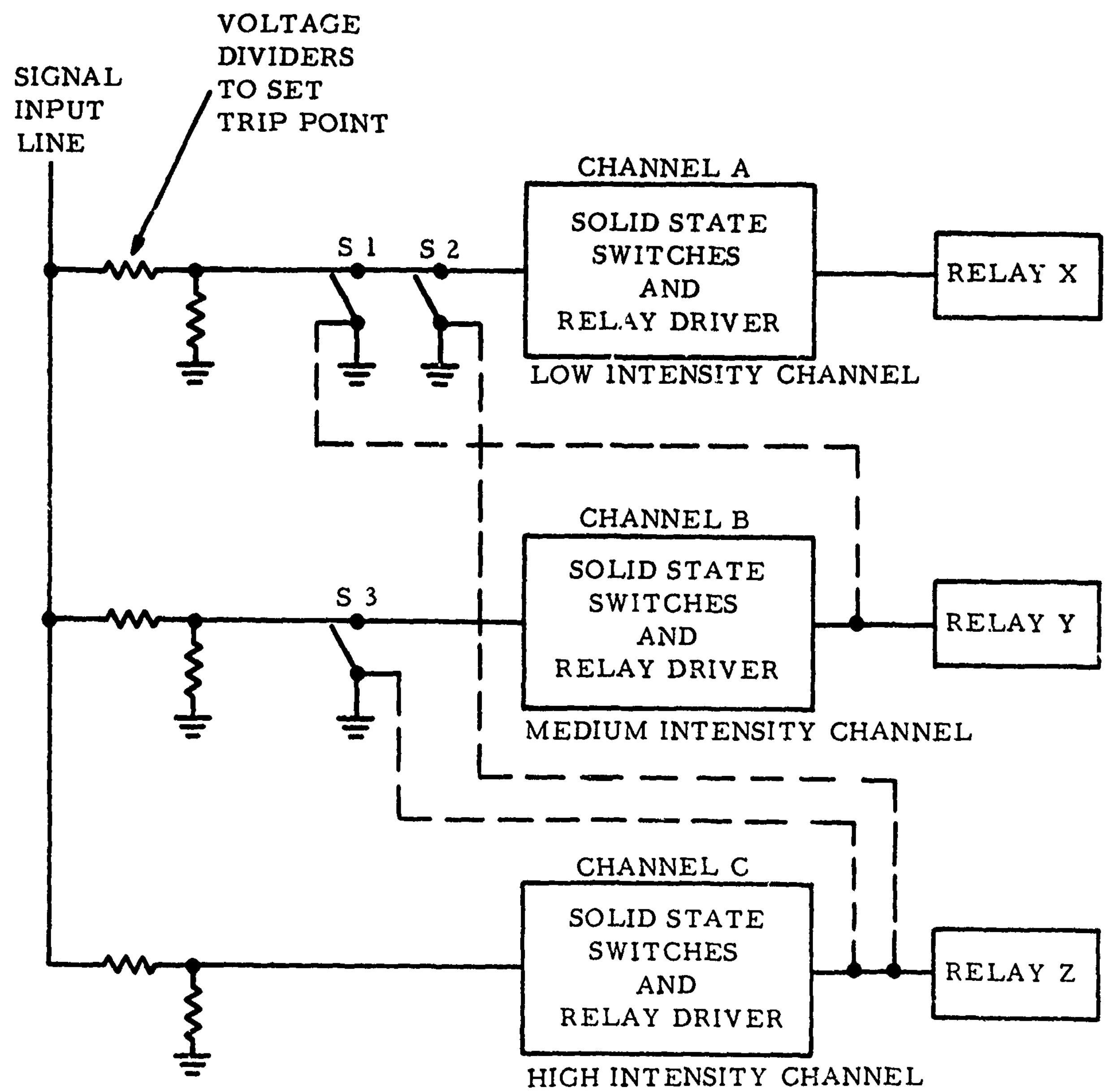


FIGURE 6 BLOCK DIAGRAM, LOGIC CIRCUIT

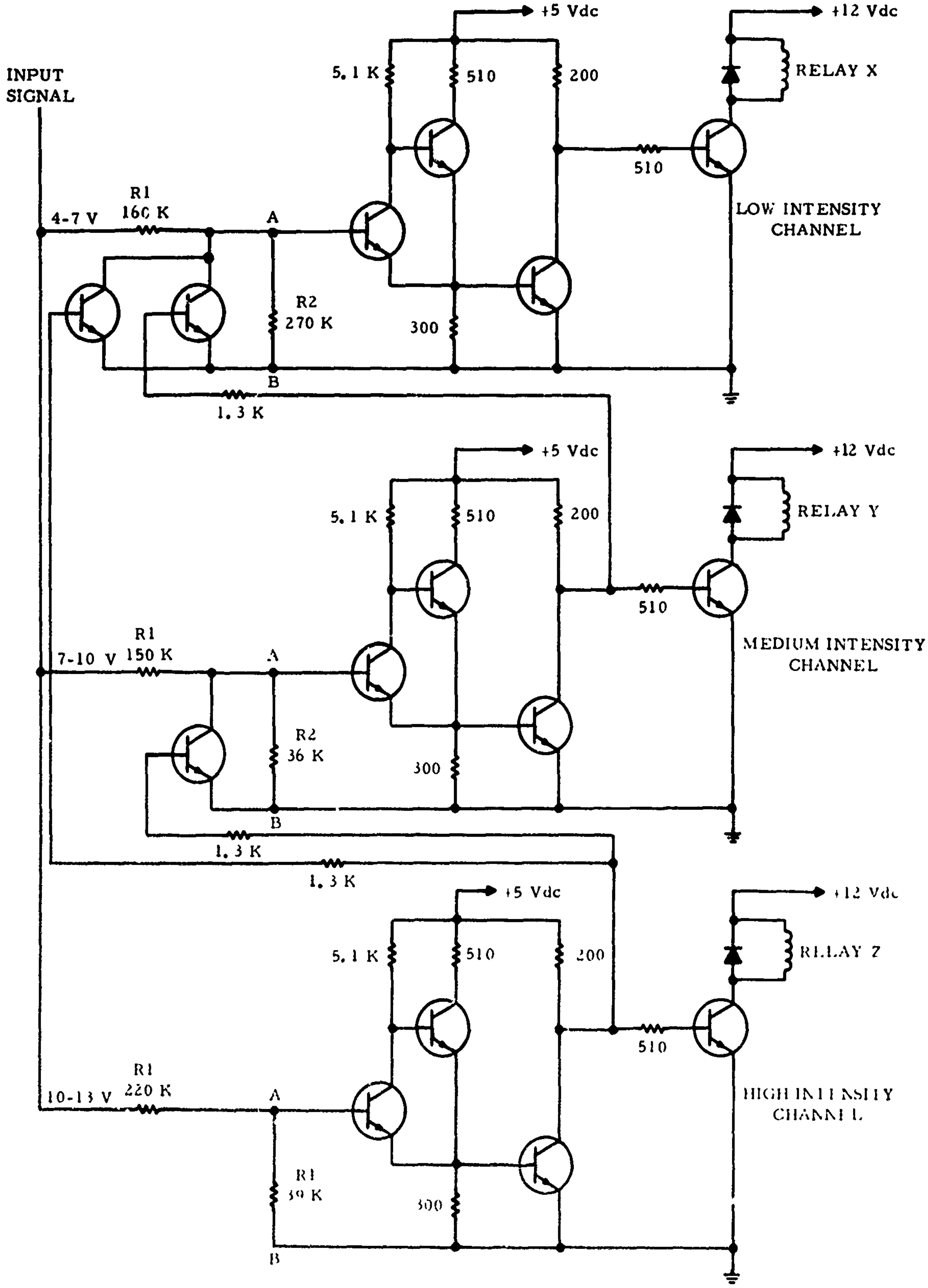


FIGURE 7 CIRCUIT DIAGRAM, LOGIC CIRCUIT

QUESTIONNARIE

PROJECT NO. 071-312-01X

Rny. 4___ or Rny. 13___

PILOT__________ AIRCRAFT______________DATE___________

WEATHER______________________________TIME____________________

1. Did you request an intensity different than that programmed in the test plan for the-

	Yes	No
Runway edge lights?	________	______
Approach (steady burning) lights?	________	______
Strobe (flasher) lights?	________	______

2. If intensity changes were requested as indicated in question 1, did the change result in an improvement? Yes____, no ____. If the answer is yes, please explain what was changed and what improvement was obtained.

3. Was the guidance given by the combined system adequate for:

	Yes	No
a. Approach zone identification?	______	_____
b. Directional information?	______	_____
c. Roll Guidance?	______	_____
d. Height Guidance?	______	_____

4. How would you rate the usefulness of the strobe (flasher) lights.

   a. Nice to have. ____
   b. Unnecessary ____
   c. Very important. ____

5. How would you rate the usefulness of the steady-burning lights?

   a. Nice to have. ____
   b. Unnecessary. ____
   c. Very important ____

6. Did the system adequately support your operation in the weather conditions experienced? Yes____ No____.

7. Please provide additional comments on reverse side.

FIGURE 8. - PILOT QUESTIONNAIRE

TABLE 1 MALSR AND RUNWAY EDGE LIGHT INTENSITIES

RUNWAY EDGE LIGHTS	3000 ft MALSR		2400 ft MALSR	
	MALS	RAILS	MALS	RAILS
STEP 5 19000 CANDLES (cd)	STEP 5 (HIGH) 6500 cd	HIGH 15000 cd	STEP 5 HIGH 6500 cd	HIGH 15000 cd
STEP 3 760 cd	STEP 4 1300 cd	MEDIUM 4000 cd & 1200 cd	STEP 4 1300 cd	MEDIUM 4000 cd
STEP 2 152 cd	STEP 3 260 cd	LOW 130 cd	STEP 3 260 cd	LOW 130 cd

APPENDIX A

PHOTOMETRIC TESTS AND DRAWING MODIFICATION

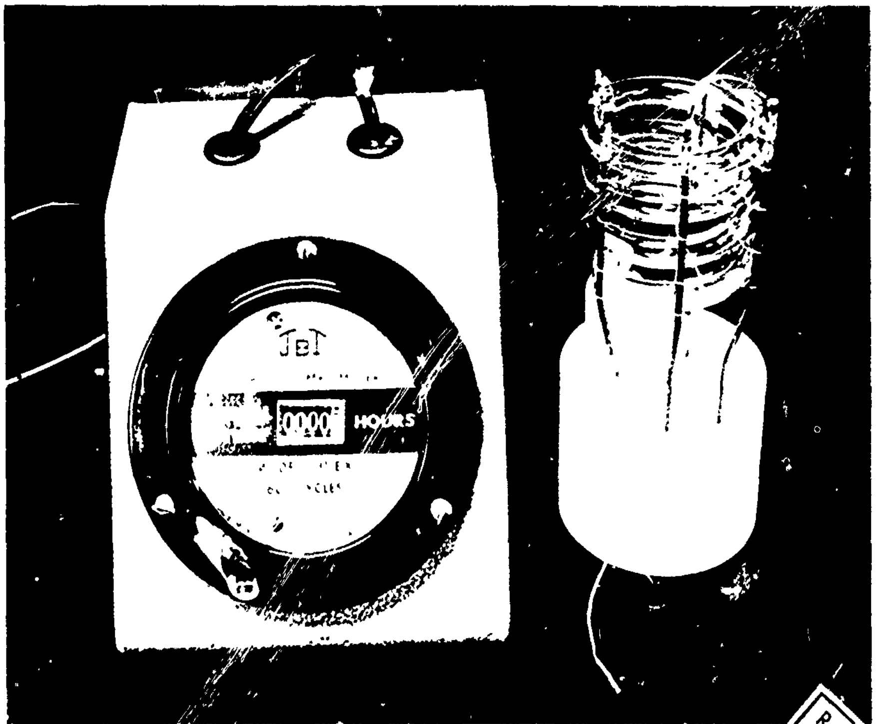


FIGURE 1-1 FLASH TUBE LIFE TEST (ZERO HOURS)

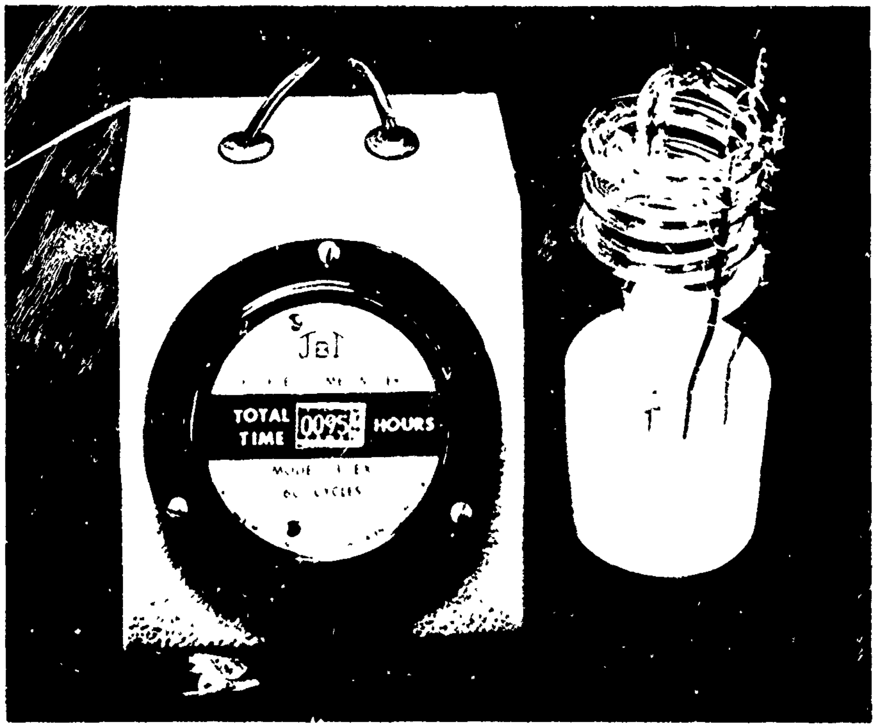


FIGURE 1-2 FLASH TUBE LIFE TEST (95 HOURS)

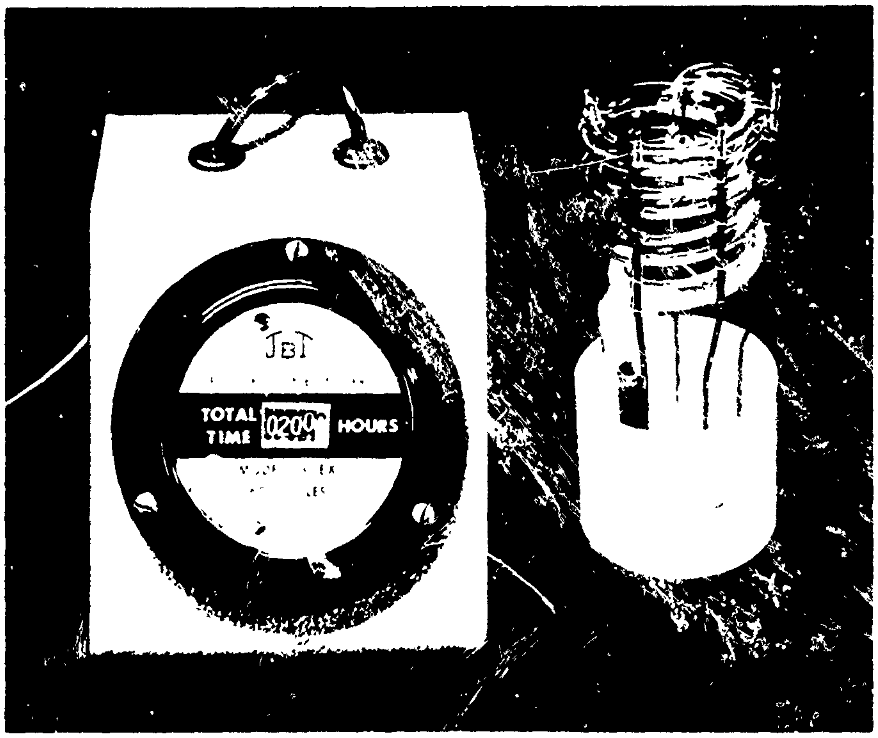


FIGURE 1-3 FLASH TUBE LIFE TEST (200 HOURS)

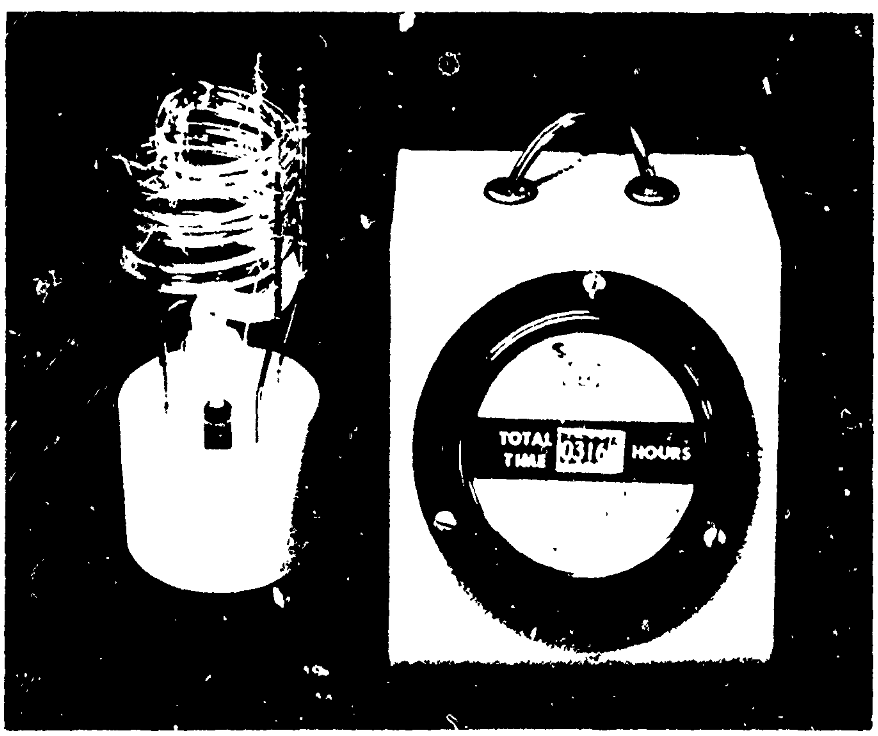


FIGURE 1-4 FLASH TUBE LIFE TEST (316 HOURS)

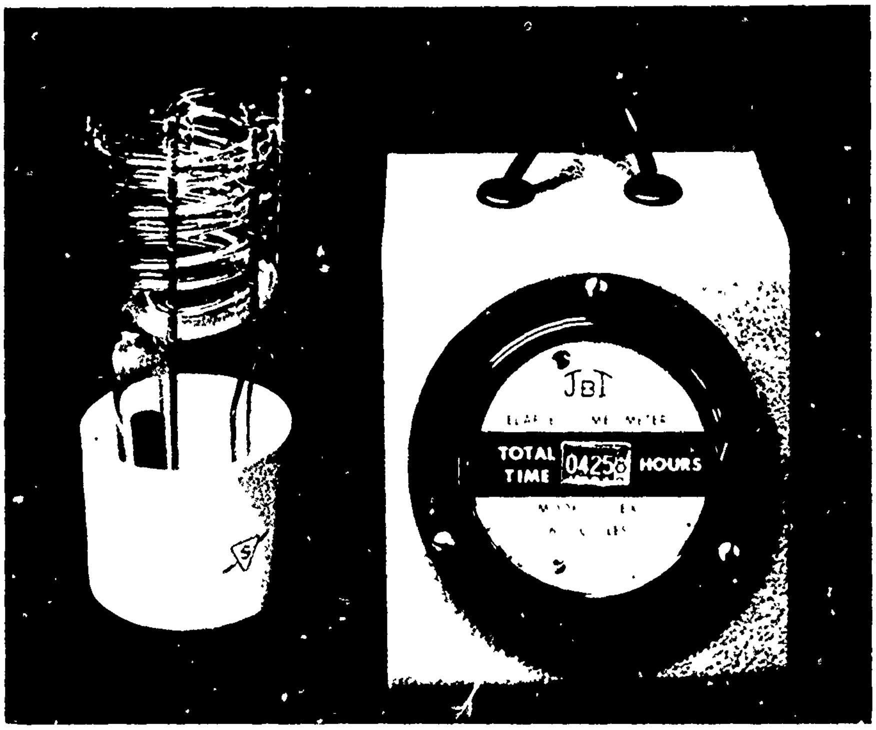


FIGURE 1-5 FLASH TUBE LIFE TEST (425 HOURS)

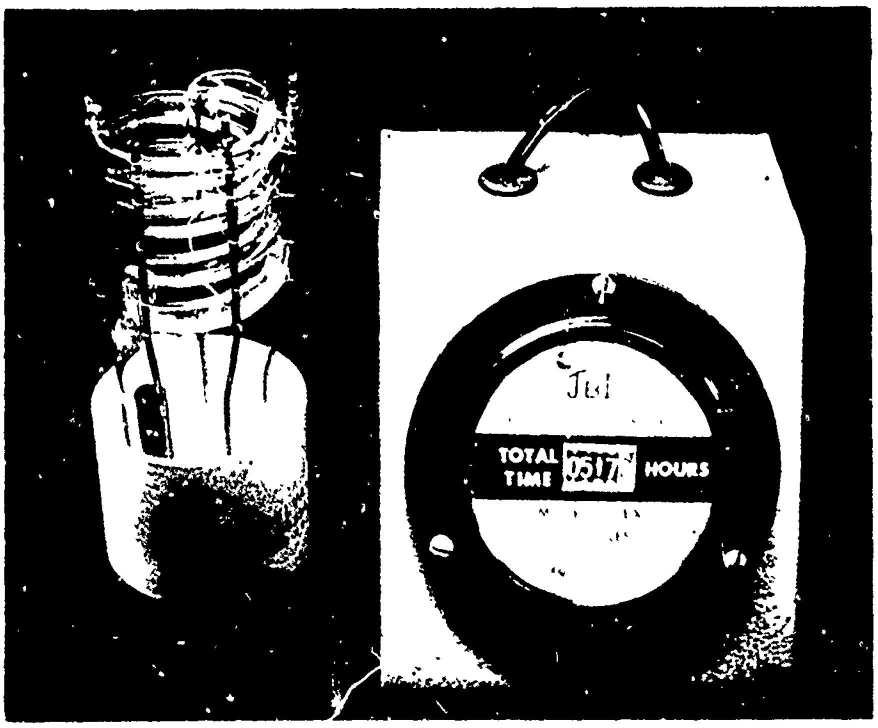


FIGURE 1-6 FLASH TUBE LIFE TEST (517 HOURS)

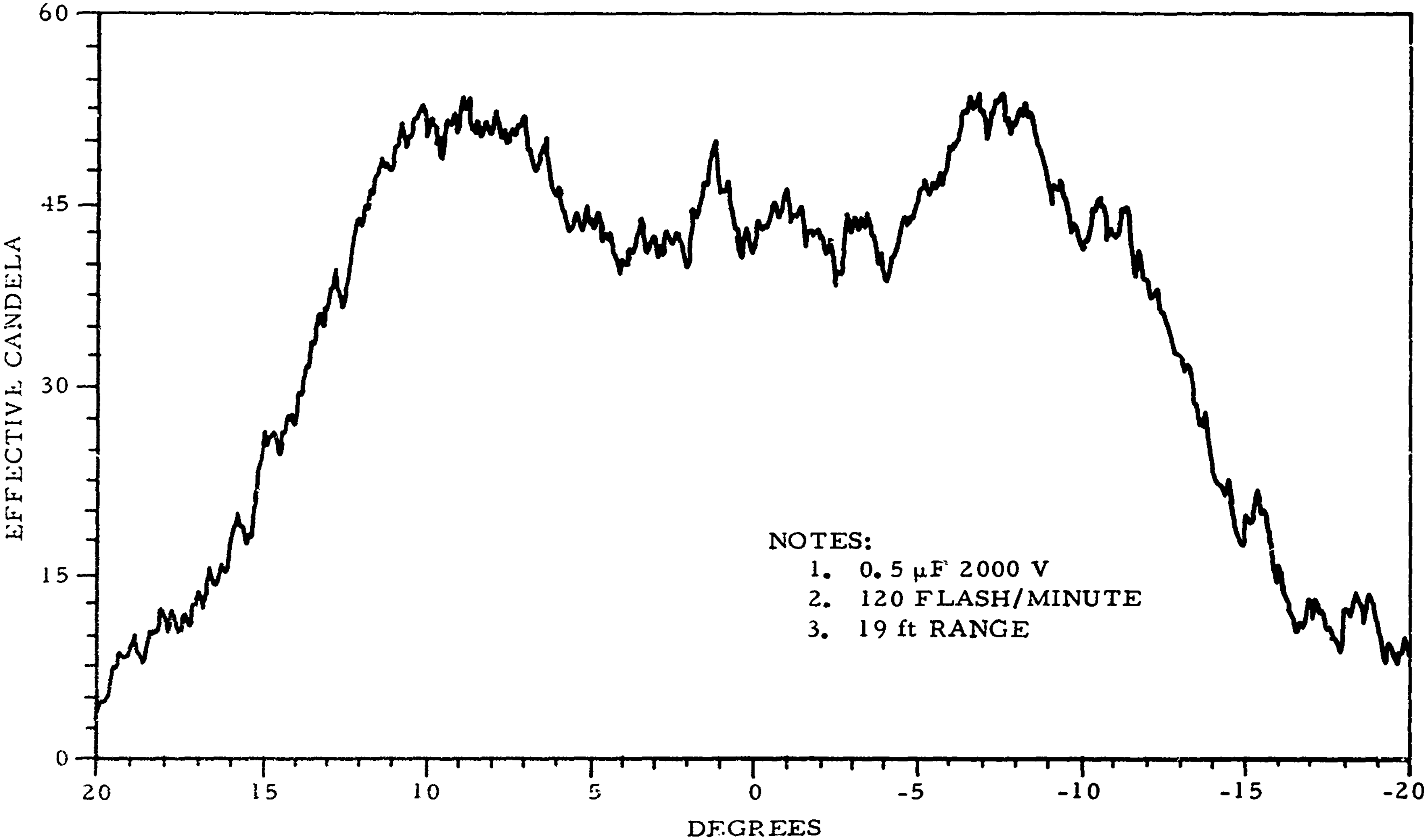


FIGURE 1-7 VERTICAL TRAVERSE OF 0.5 uF CAPACITOR
AT ZERO DEGREES AZIMUTH

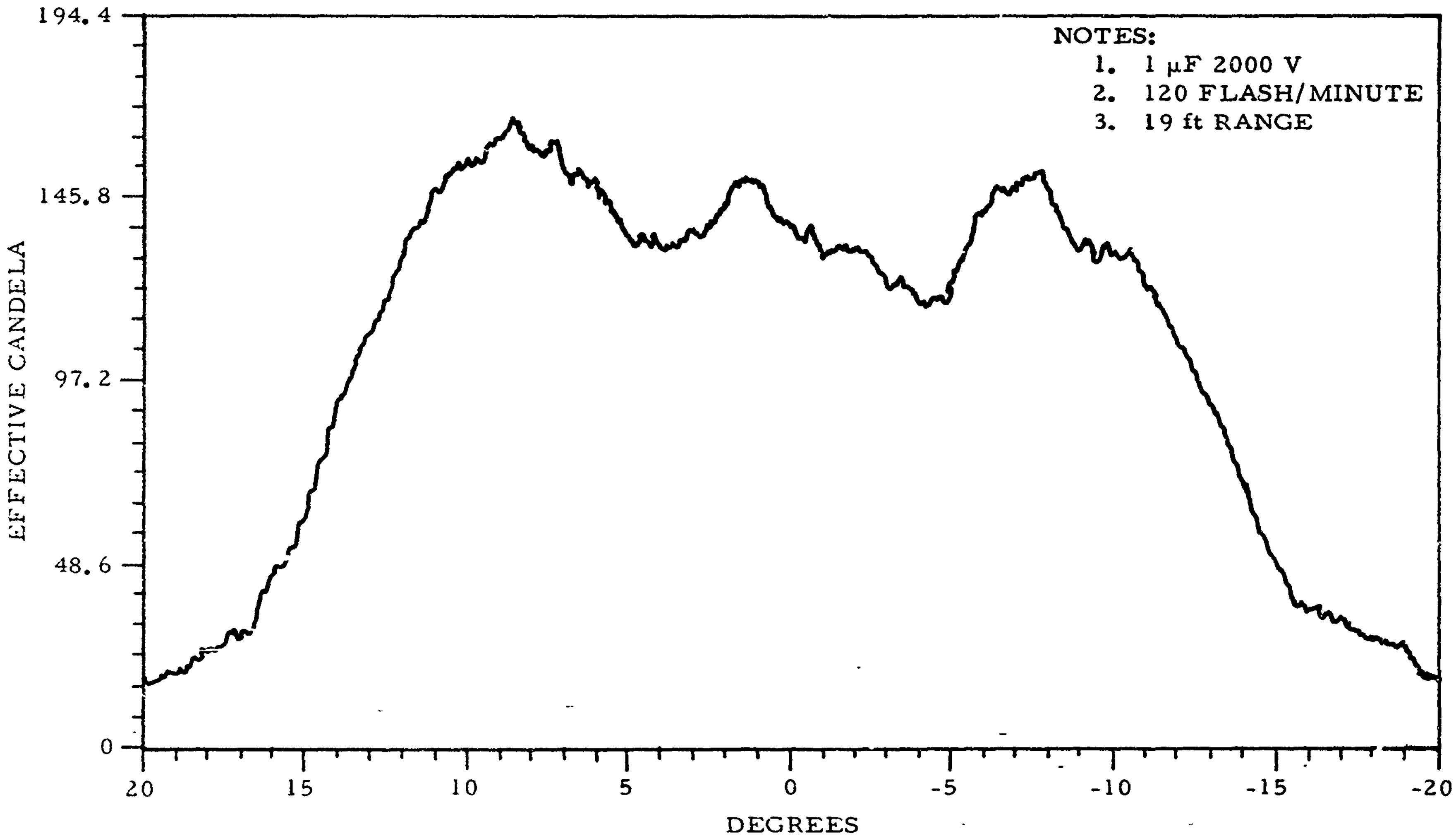


FIGURE 1-8 VERTICAL TRAVERSE OF 1.0 uF CAPACITOR AT ZERO DEGREES AZIMUTH

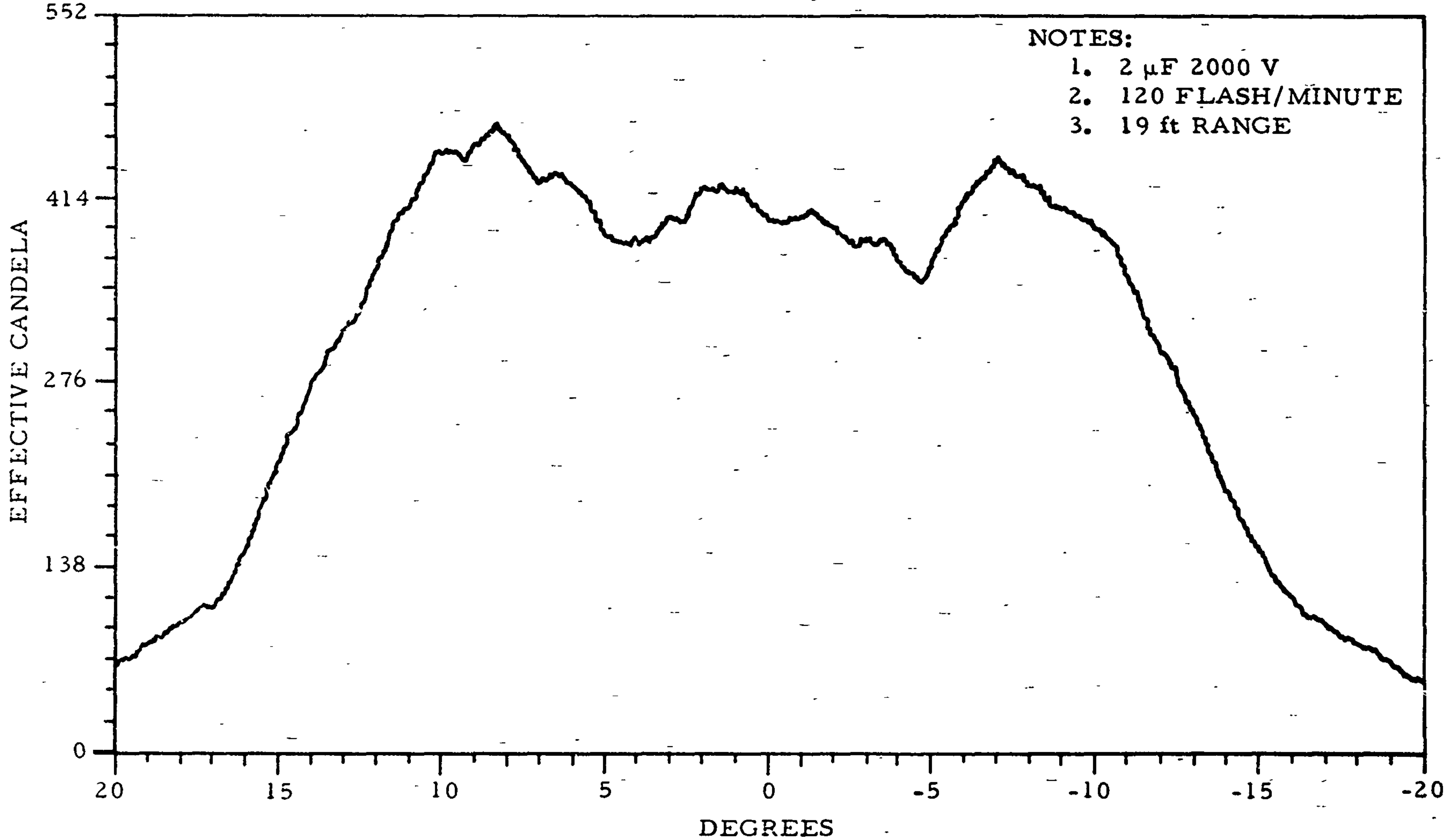


FIGURE 1-9 VERTICAL TRAVERSE OF 2 uF CAPACITOR AT ZERO DEGREES AZIMUTH

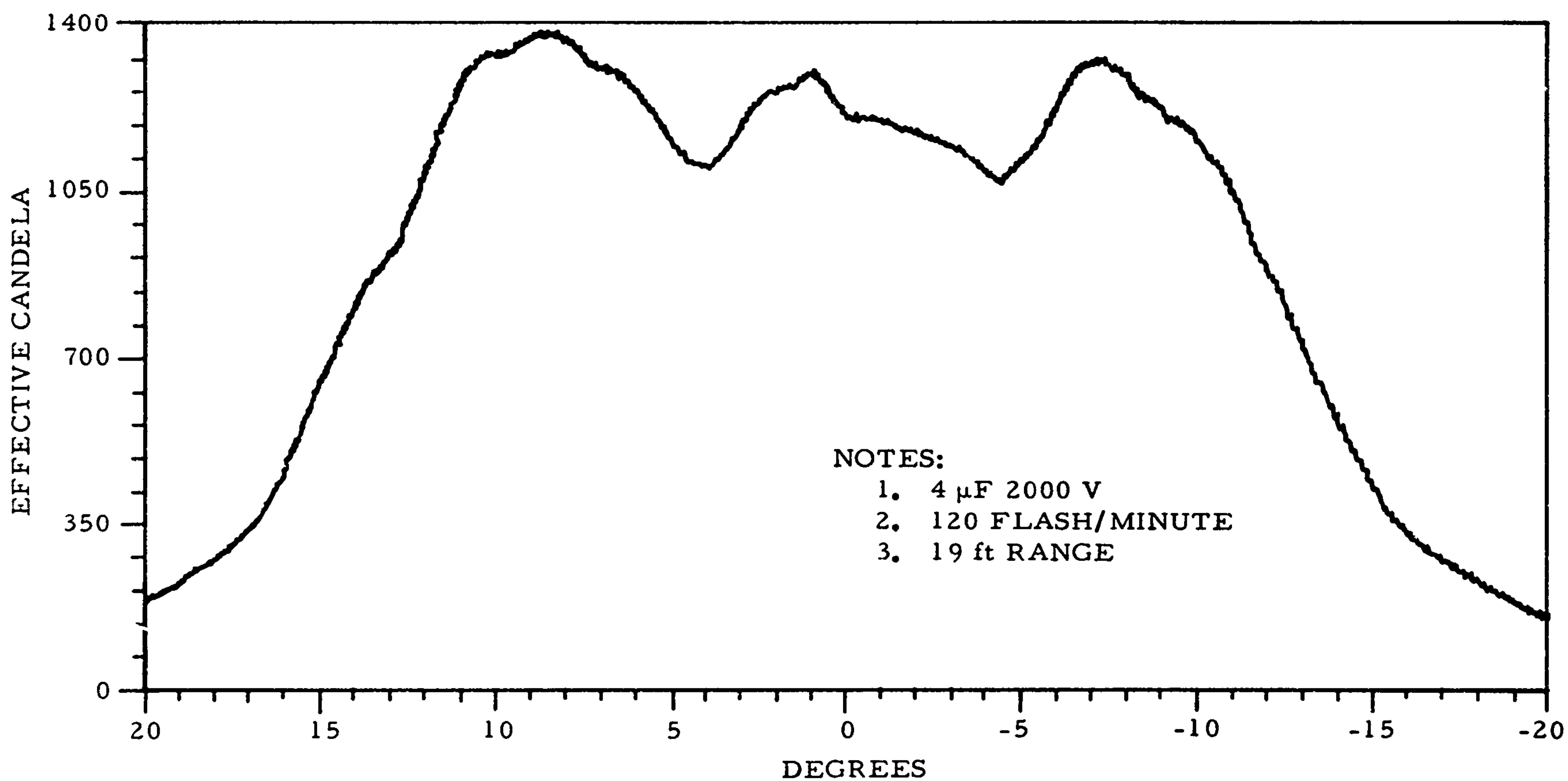


FIGURE 1-10 VERTICAL TRAVERSE OF 4 uF CAPACITOR AT ZERO DEGREES AZIMUTH

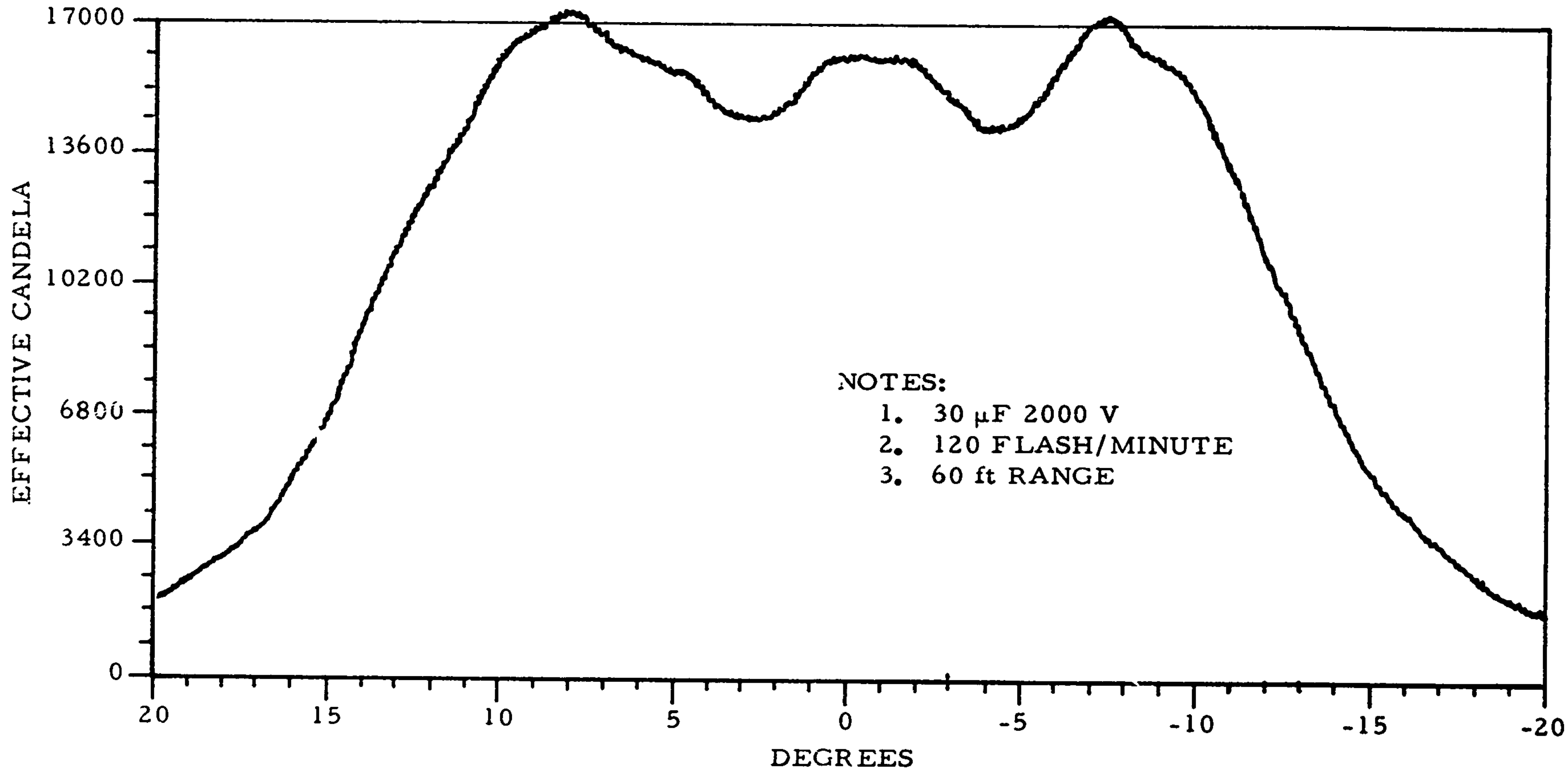


FIGURE 1-11 VERTICAL TRAVERSE OF 30 uF CAPACITOR AT ZERO DEGREES AZIMUTH

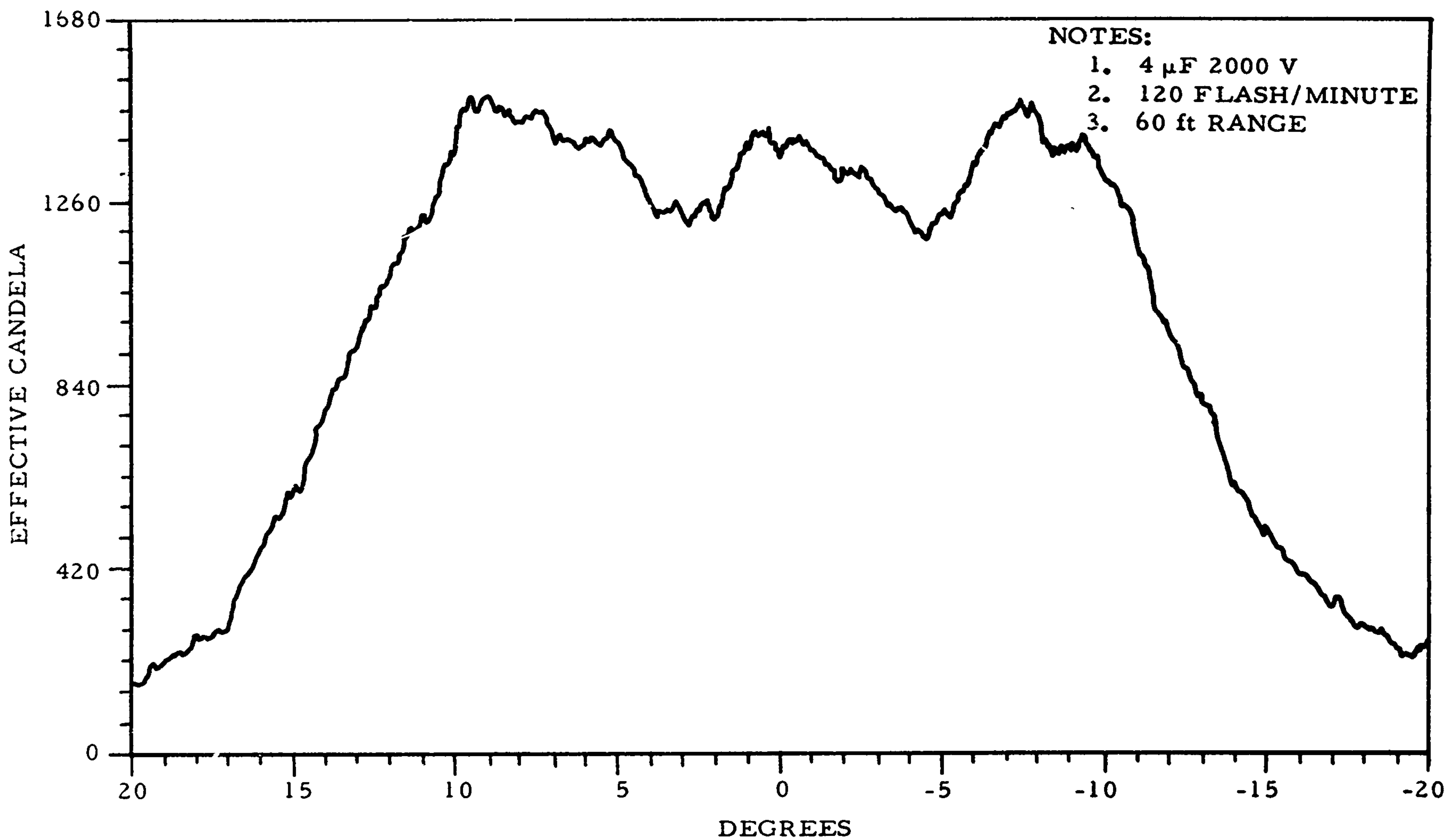


FIGURE 1-12 VERTICAL TRAVERSE OF 4 uF CAPACITOR AT ZERO DEGREES AZIMUTH

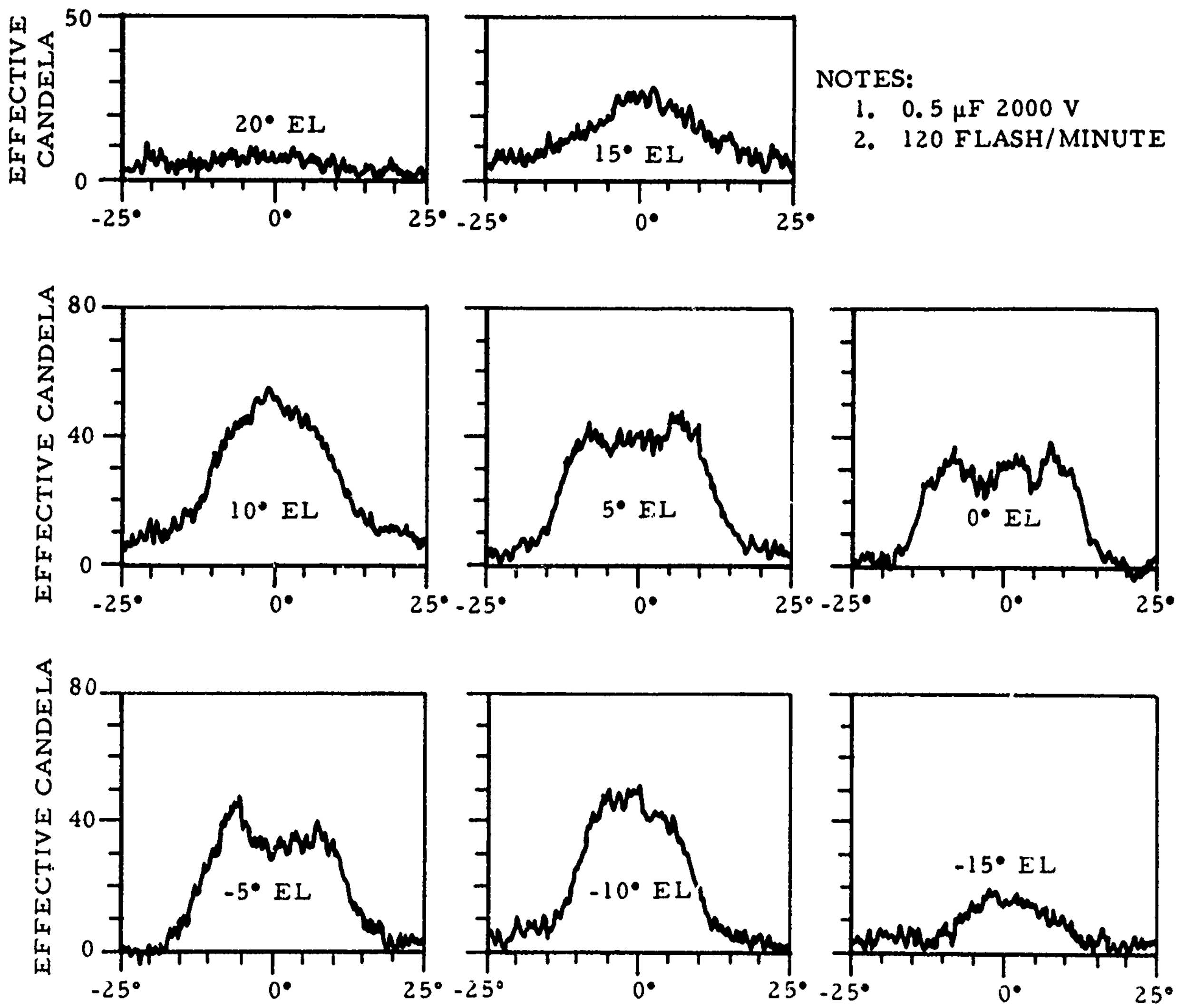


FIGURE 1-13 HORIZONTAL TRAVERSES OF 0.5 uF CAPACITOR

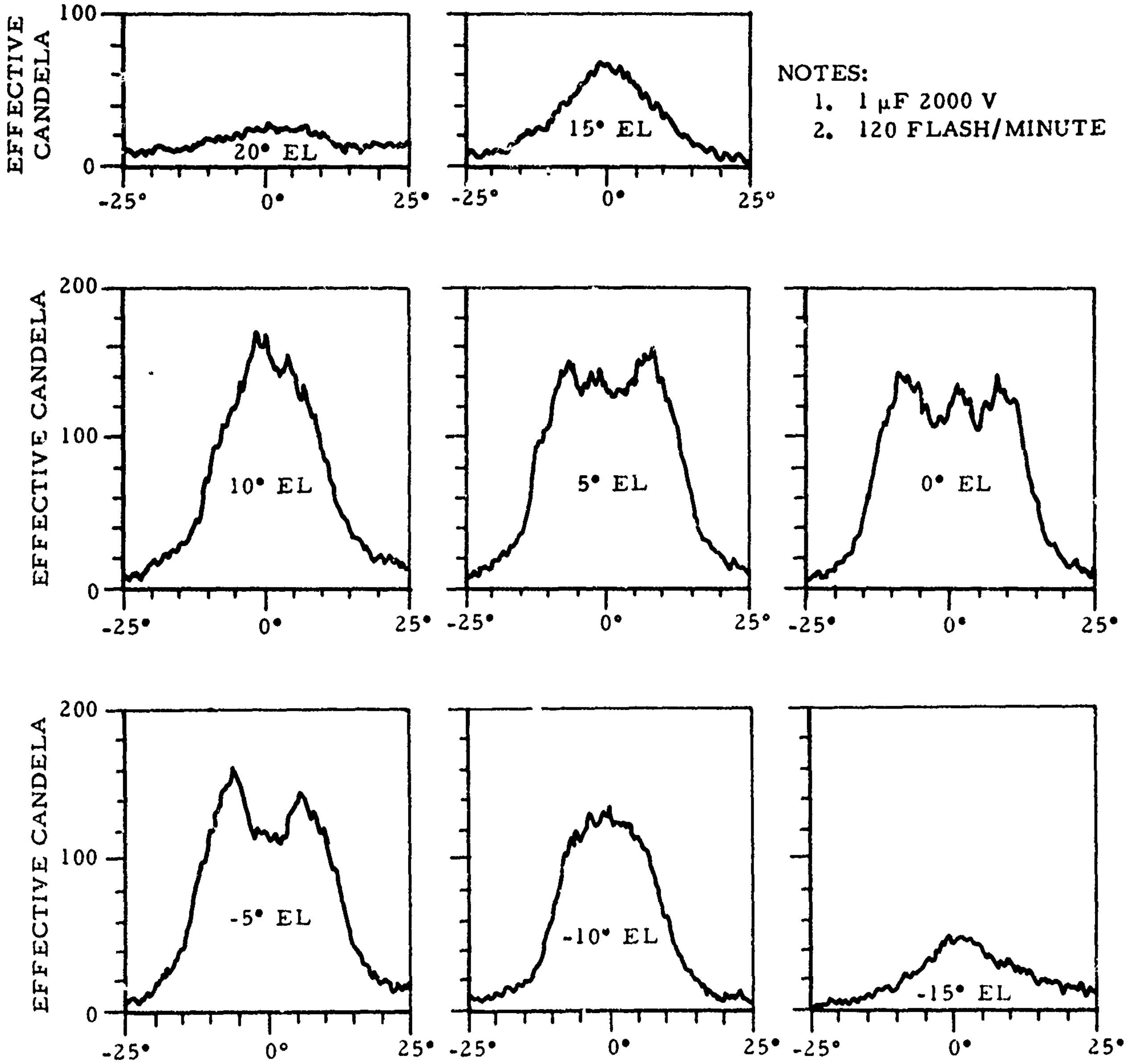


FIGURE 1-14 HORIZONTAL TRAVERSES OF 1 uF CAPACITOR

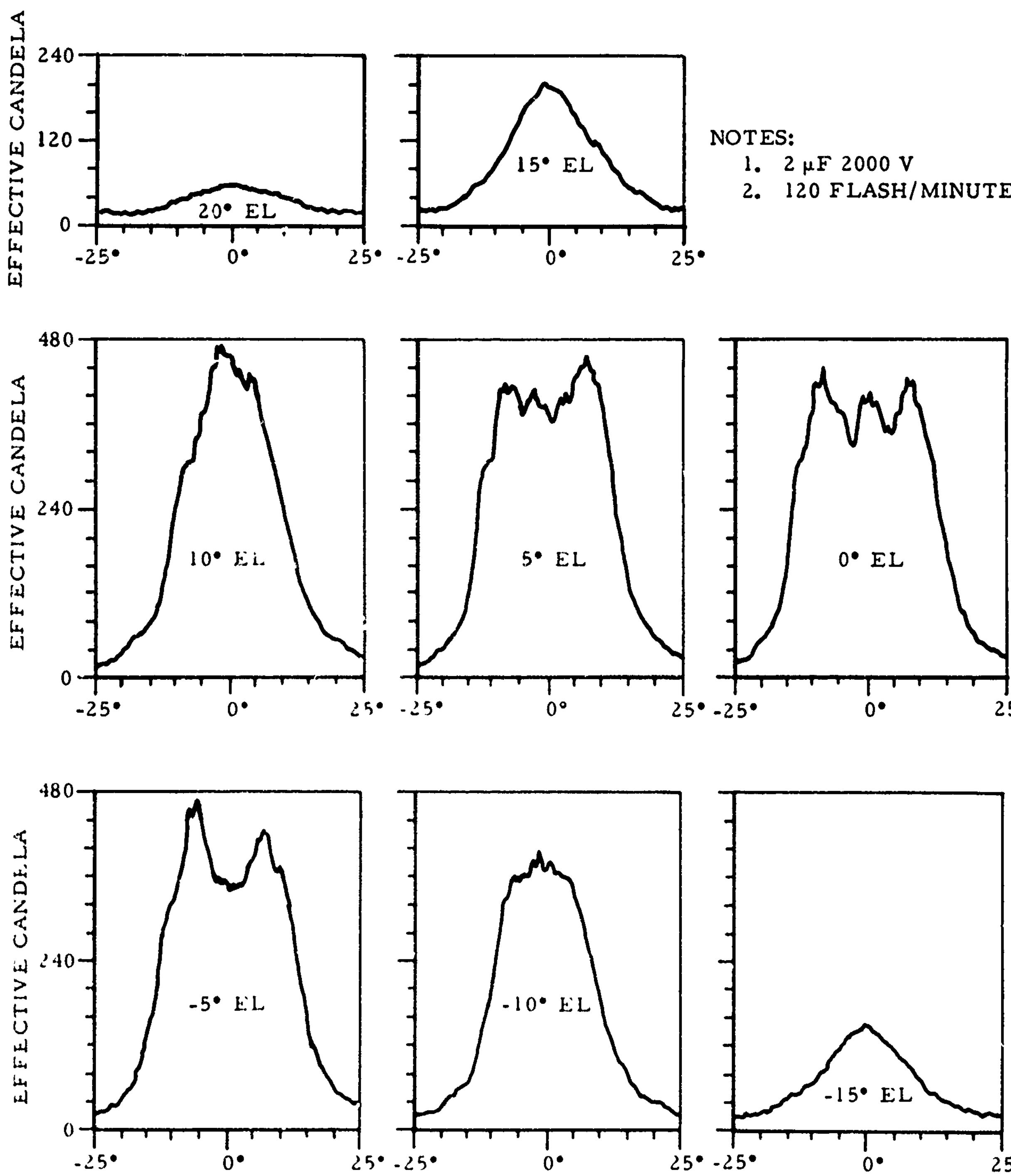


FIGURE 1-15 HORIZONTAL TRAVERSES OF 2 uF CAPACITOR

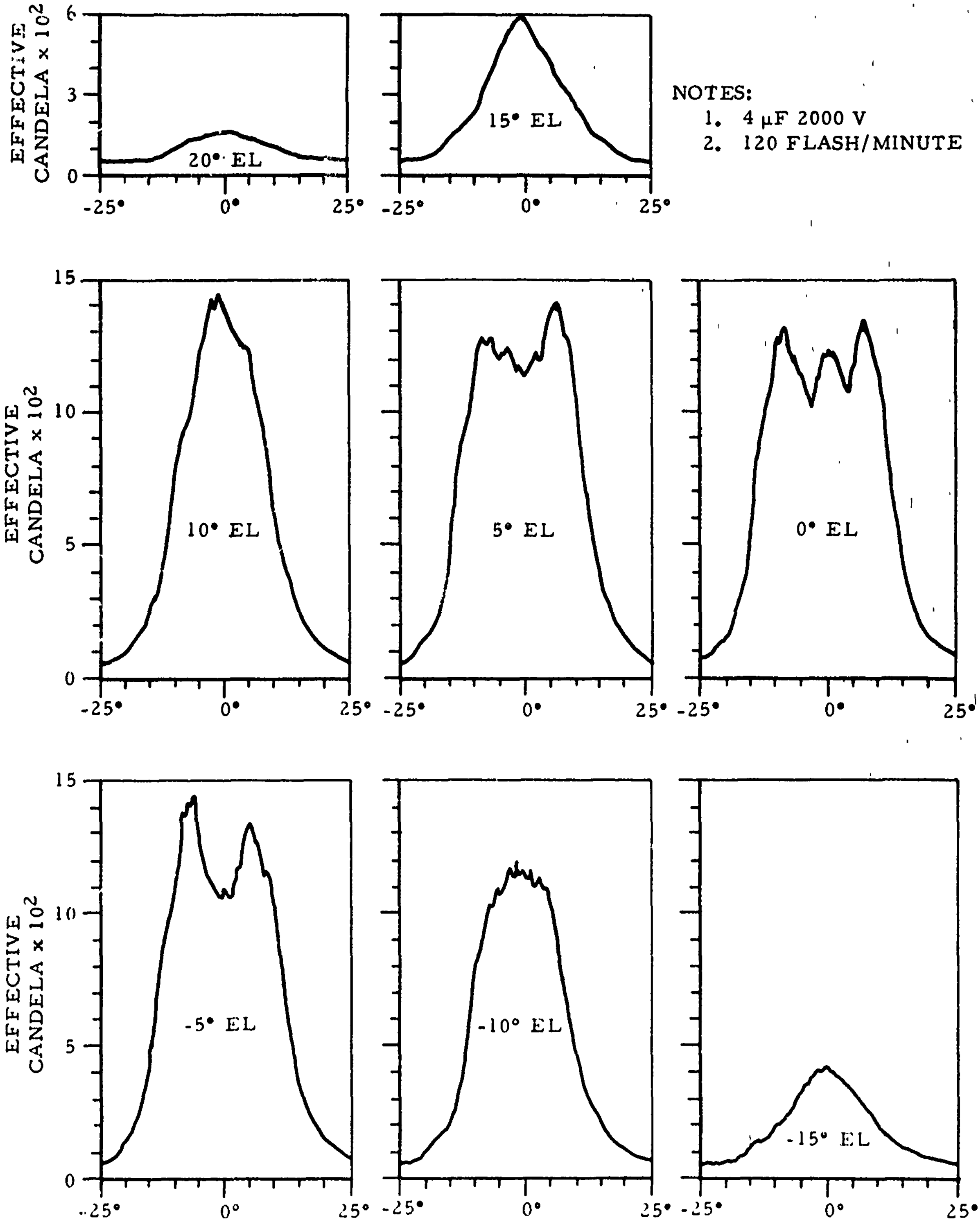


FIGURE 1-16 HORIZONTAL TRAVERSES OF 4 uF CAPACITOR

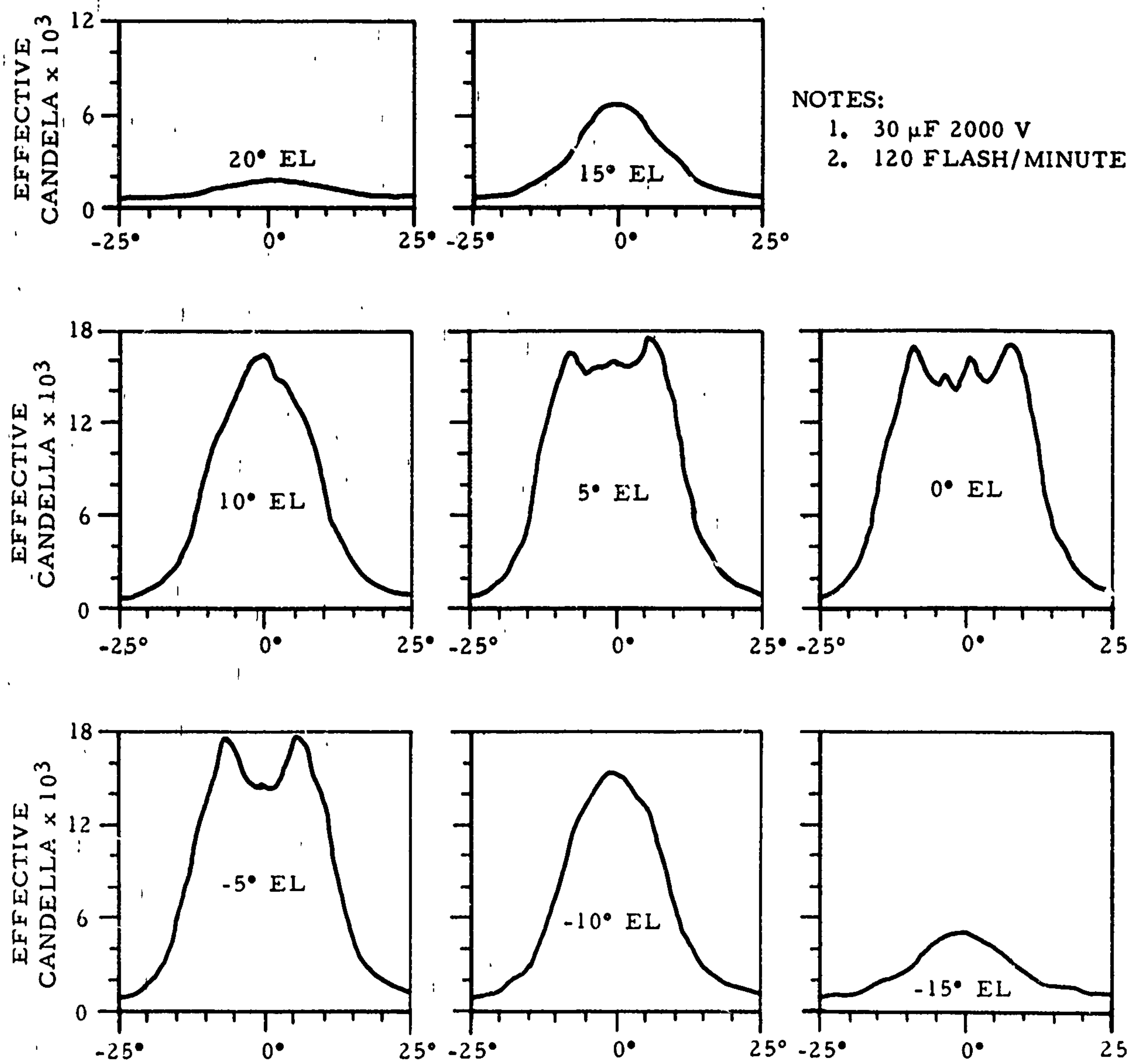
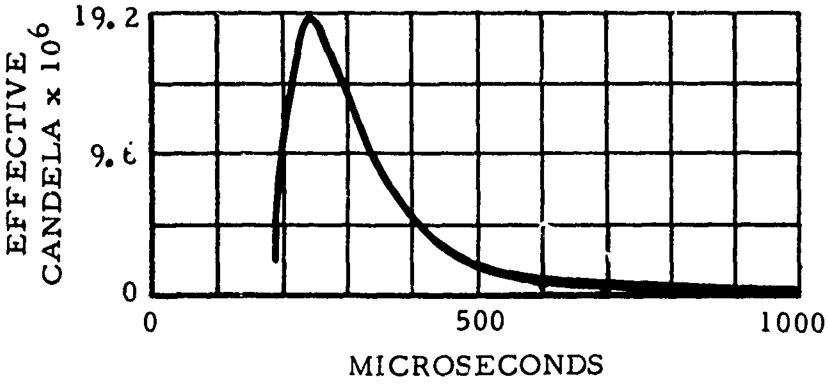
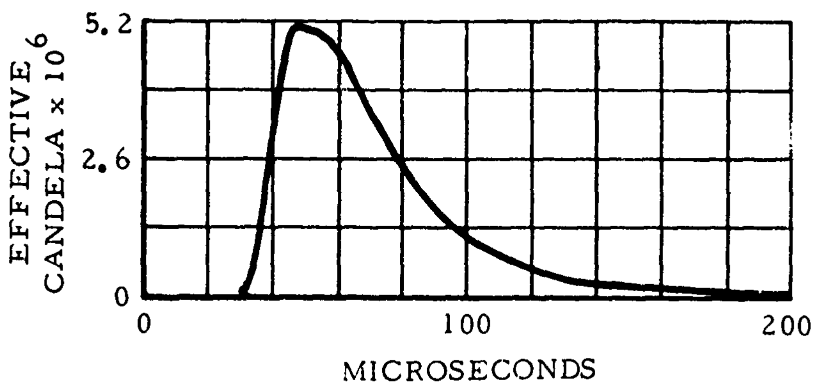


FIGURE 1-17 HORIZONTAL TRAVERSES OF 30 uF CAPACITOR

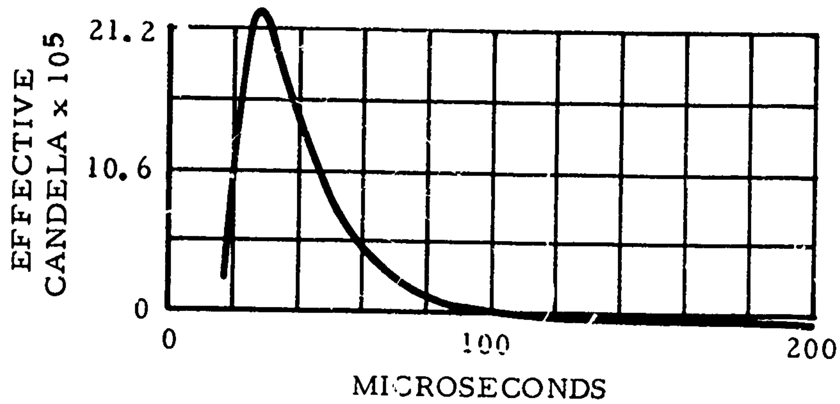


NOTES:
1. 30 MICROFARAD STORAGE CAPACITOR.
2. PHOTOMETER OUTPUT PULSE.

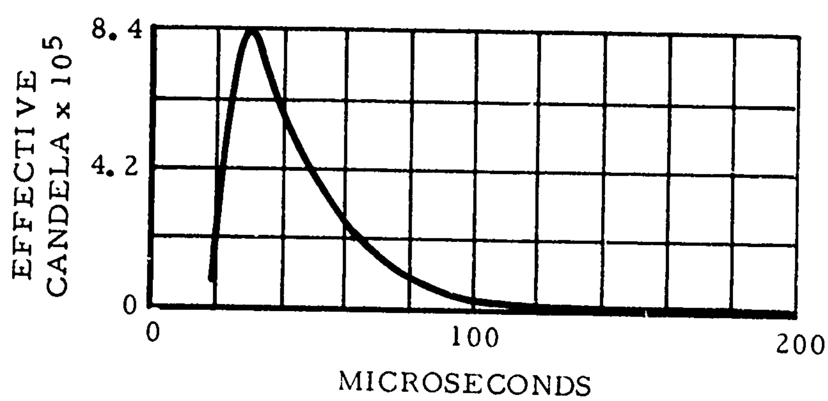


NOTES:
1. 4 MICROFARAD STORAGE CAPACITOR.
2. PHOTOMETER OUTPUT PULSE.

FIGURE 1-18 FLASHER PHOTOMETER OUTPUT PULSES OF 4 uF, 30 uF CAPACITORS

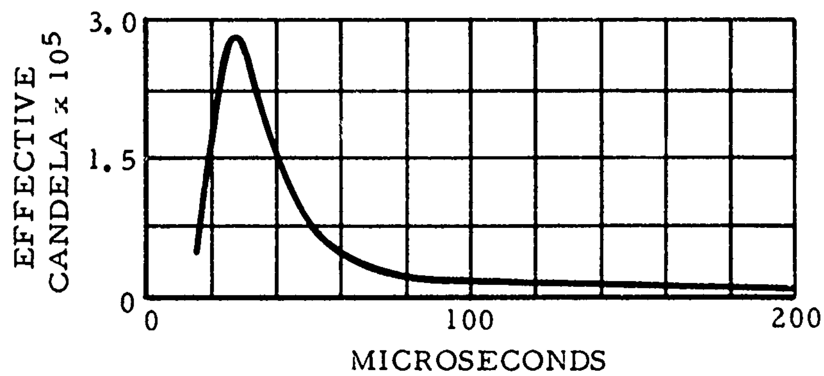


NOTES:
1. 2 MICROFARAD STORAGE CAPACITOR.
2. PHOTOMETER OUTPUT PULSE.



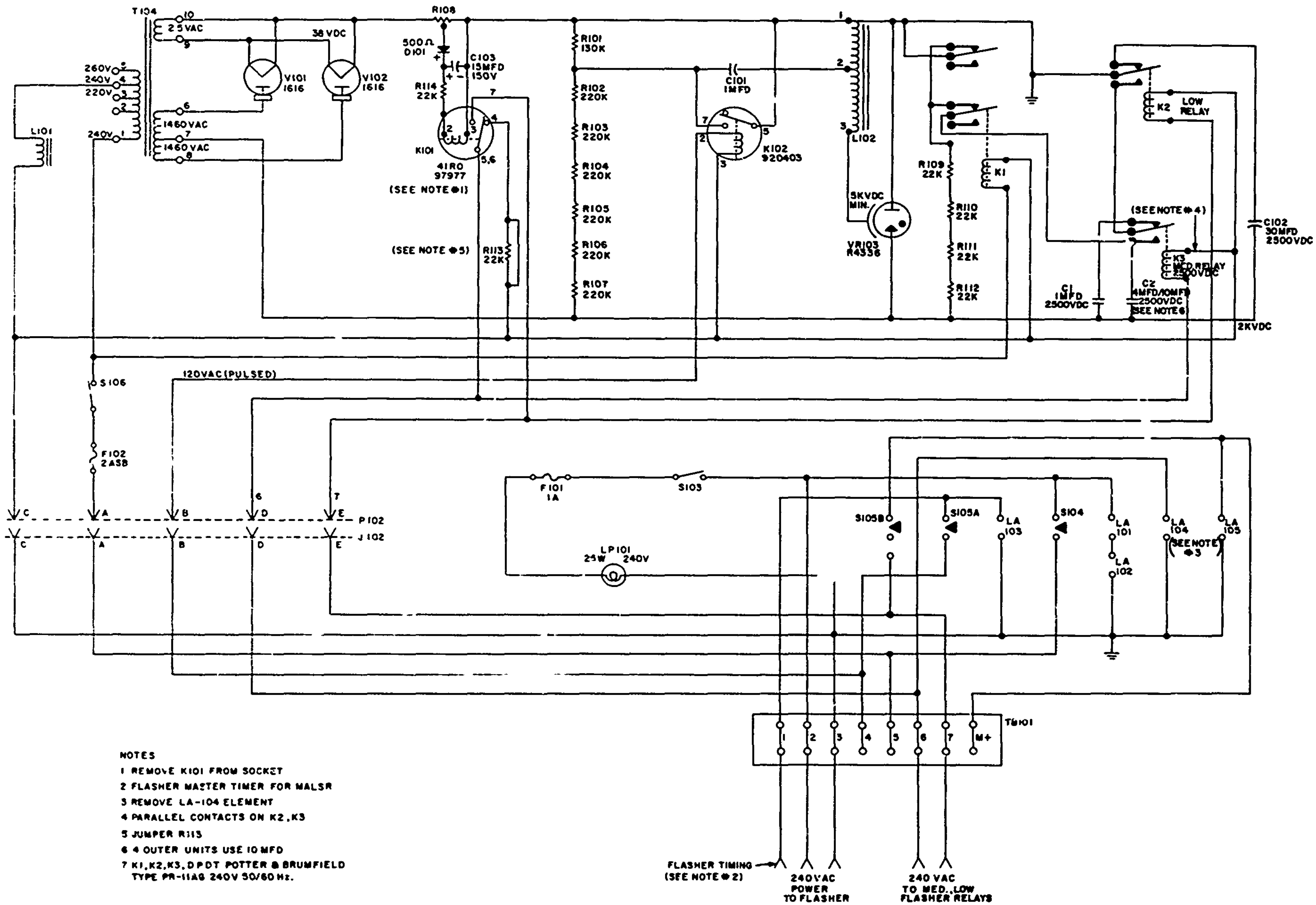
NOTES:
1. 1 MICROFARAD STORAGE CAPACITOR.
2. PHOTOMETER OUTPUT PULSE.

FIGURE 1-19 FLASHER PHOTOMETER OUTPUT PULSES OF 2 uF, 1 uF CAPACITORS



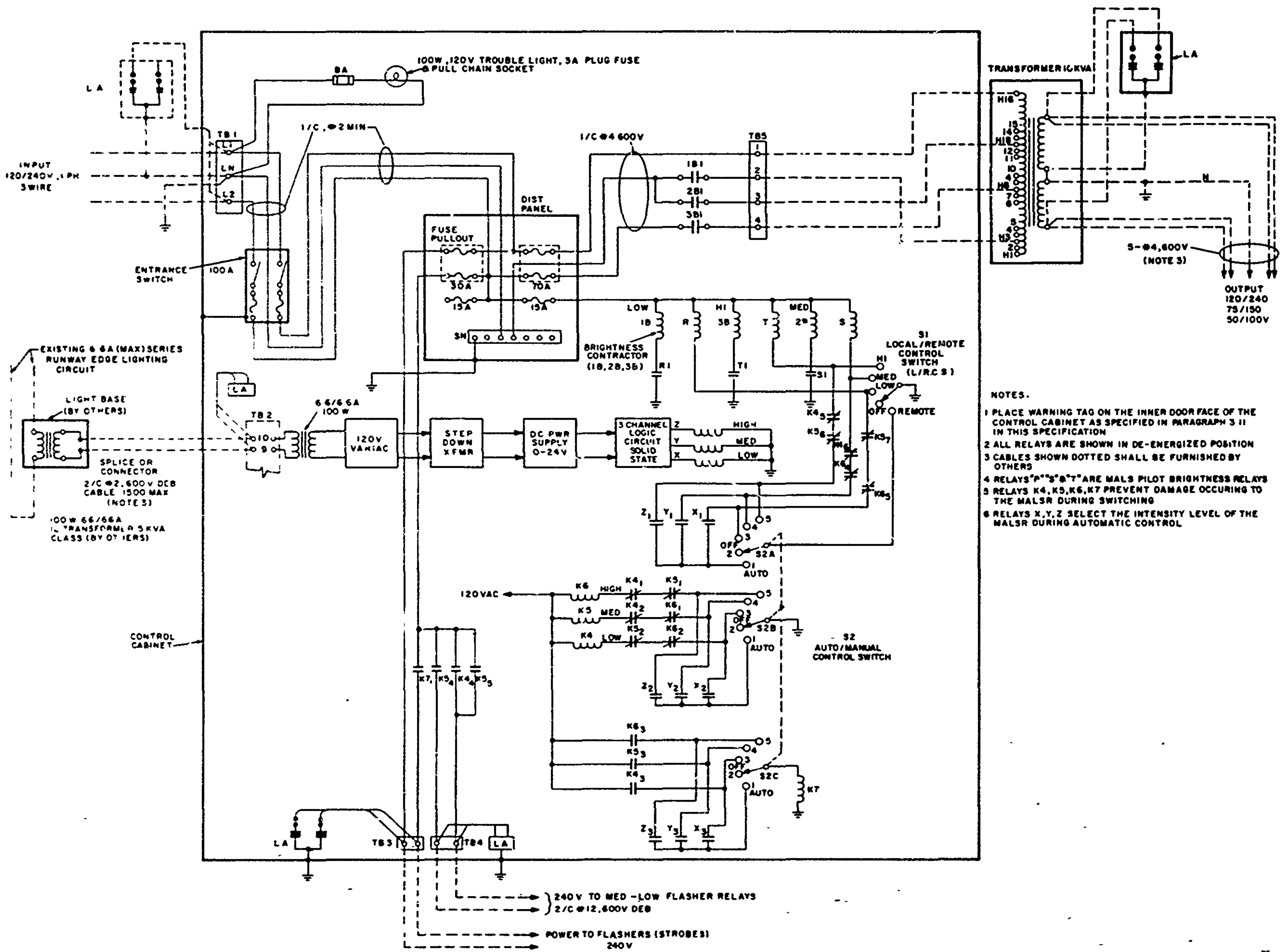
NOTES:
1. 0.5 MICROFARAD STORAGE CAPACITOR.
2. PHOTOMETER OUTPUT PULSE.

FIGURE 1-20 FLASHER PHOTOMETER OUTPUT PULSES OF 0,5 uF CAPACITORS



NOTES
1 REMOVE K101 FROM SOCKET
2 FLASHER MASTER TIMER FOR MALSR
3 REMOVE LA-104 ELEMENT
4 PARALLEL CONTACTS ON K2, K3
5 JUMPER R113
6 4 OUTER UNITS USE 10 MFD
7 K1, K2, K3, DPDT POTTER & BRUMFIELD TYPE PR-11AG 240V 50/60 Hz.

FIGURE 1-21 FAA-1106 MODIFIED FOR INTENSITY CONTROL



NOTES.

1. PLACE WARNING TAG ON THE INNER DOOR FACE OF THE CONTROL CABINET AS SPECIFIED IN PARAGRAPH 3.11 IN THIS SPECIFICATION
2. ALL RELAYS ARE SHOWN IN DE-ENERGIZED POSITION
3. CABLES SHOWN DOTTED SHALL BE FURNISHED BY OTHERS
4. RELAYS "R" "S" "& "T" ARE MALS PILOT BRIGHTNESS RELAYS
5. RELAYS K4, K5, K6, K7 PREVENT DAMAGE OCCURING TO THE MALSR DURING SWITCHING
6. RELAYS X, Y, Z SELECT THE INTENSITY LEVEL OF THE MALSR DURING AUTOMATIC CONTROL

FIGURE 1-22 MALSR POWER AND CONTROL WIRING DIAGRAM

APPENDIX B

SUMMARY OF PILOT QUESTIONNAIRE DATA

SUMMARY OF PILOT QUESTIONNAIRE DATA, PROJECT 071-312-01X, "Flight Test of MALS/RAILS With Intensity Control"

BACKGROUND

The Medium Intensity Approach Lighting System (MALS) and the Runway Alignment Indicator Lights (RAILS) were developed as potential visual guidance systems for runways lacking a full approach light system (ALS). MALS is 1,400 feet long and contains steady burning lights patterned after those of the full ALS. The RAIL system consists of sequence flashing lights (strobes) beginning at the end of MALS and extending out an additional 1,000 feet or an additional 1,600 feet, to constitute either a 2,400-foot or a 3,000-foot total system. RAILS used with MALS in this configuration is labeled MALS/RAILS or simply MALSR.

Condenser discharge elements in earlier ALS's have generally had only a maximum setting. If found to be too bright, they could be turned off, but not turned down to a lower intensity, as could the various steady burning elements. A principal feature of this test was provision of intensity steps on the strobes as well as on the steady burning elements of ALS and runway lights. Further, an attempt was made to establish intensity steps for each lighting element that would be compatible with the general illumination conditions of day versus night and VFR minimums versus IFR conditions.

After the tests had been completed in part, and considerable evidence had been accumulated at a 3,000-foot-long MALSR, it was decided to test a 2,400-foot-long system. Due to failure to obtain a waiver of landing minimums on runway 4, where it was desired but not allowed to conduct VOR approaches down to 1/2-mile visibility, a portion of the flights was switched to runway 13 where ILS approaches could be made. The result of these arrangements was that flights were conducted on two lengths of system, one length being duplicated by VOR approaches to one runway and ILS approaches to another, by day and night, and at night under low visibility conditions (IFR) and longer visibilities. Table 2-1 summarizes the experimental conditions.

There are two principal questions for analysis. First, did the pilots find the 3,000-foot and the 2,400-foot-long systems to provide adequate guidance under the various conditions of visibility? Second, were the preselected intensity steps on lighting elements satisfactory? Since it is

considered that the differences between the two 3,000-foot-long systems were not great enough from the pilot's eye position to matter, and that the differences in instrument procedures should not detract materially from the meaningfulness of the questionnaire data, it was decided to pool the results on the two longer systems. This produced the distribution of questionnaires shown in Table 2-2.

TABLE 2-1. - NUMBER OF QUESTIONNAIRES RECEIVED UNDER EACH CONDITION

	Length of System		
	2,400 Feet	3,000 Feet	
	RW 4	RW 4	RW 13
Day IFR	11	7	7
Night IFR	9	0	9
Night VFR	16	15	2

TABLE 2-2. - NUMBER OF QUESTIONNAIRES BY LENGTH OF SYSTEM

	Length of System	
	2,400 Feet	3,000 Feet
Day IFR	11	14
Night IFR	9	9
Night VFR	16	17

RESULTS

Day IFR

3,000-Foot-Long System: In day IFR conditions, 14 series of approaches were conducted by 12 different pilots in the Aero Commander, Gulfstream, and Convair 580 aircraft. On the four different days a reasonably wide variety of daytime reduced visibility conditions was experienced, ceiling varying from 200 feet, with 1/2-mile visibility, to 700 feet and 4 miles. This insured that the preselected intensity settings, which were step 5 for the MALS, step 5 for the runway edge lights, and step 3 for the RAILS, would be tested against a variety of day IFR ambient brightnesses.

Since a primary focus of the test was the suitability of the preselected intensity steps, the first question asked "Did you request an intensity different than that programmed... for the runway edge lights? Approach (steady burning) lights? Strobe lights?" In all 14 responses from the 12 pilots the answers were no. Hence, the actual behavior of the pilots gave no grounds to believe that the intensity steps were found to be grossly out of line. The second question was a follow-up to the first, asking whether intensity changes requested resulted in improvement. Since none of the runs had produced requests for changes, this query was void.

The third item asked "Was the guidance given by the combined system adequate for: a. Approach zone identification? b. Directional information? c. Roll guidance? d. Height guidance?" If an approach light system does anything at all, it must identify the approach zone and give directional information. The 3,000-foot-long systems under test received a near unanimous vote on these counts (14-0 saying guidance was adequate for approach zone identification and 13-1 approving the guidance for directional information). Roll guidance was conditionally approved, by a 10 yes, 2 no, 2 unsure division. Ten out of 12 answering barely meets the .05 critierion in the binomial probability table. On the final item there was an even division, 6 approving height guidance, 6 saying no, and 2 saying there was some limited height guidance present. Height guidance from visual signals other than a VASI or other special approach slope device is known to be a major problem in low visibility. Hence, it is not surprising that the pilots did not give a positive approval to the 3,000-foot economy system for this feature which is not generally approved in other tests conducted without a VASI.

Question 4 asked "How would you rate the usefulness of the strobe lights?" After 12 series of runs, the pilot replied that the strobe lights were "very important." After the remaining two series, the pilots stated that the strobes were "nice to have." In no case did the pilot select the alternative, "unnecessary." Thus, the pilots gave a high rating to the value of strobe lights in the abbreviated system.

The last of the multichoice questions repeated the same three alternatives (nice to have, unnecessary, very important) in asking "How would you rate the usefulness of the steady burning lights?" As might be expected, the results were similar to the previous question on strobes, with 11 runs resulting in a rating of "very important" and the balance going into the "nice to have" category. An approach light or runway alignment light system would be nothing at all without either steady burning or strobe lights. Both have been found to contribute in past tests, and this result is not changed when using an economy system.

The sixth question asked the overall evaluation, "Did the system adequately support your operation in the weather conditions experienced." There were 12 affirmative responses, 1 negative, and a single equivocation in which the pilot marked yes and no. This last answer, which came from a series of runs with 200-300 feet ceiling and visibility of 1-4 miles, was amplified by the comment that "clouds were below the minimum altitude, obscuring the lights from view. However, on the last approach, ceiling raised to a point where the approach light system was very helpful...." With this comment we may take the answer to mean that the system was approved when there was sufficient ceiling. Obviously, lights must be seen to be used, and the clouds may be so low that the pilot cannot get visual guidance information as soon as he wants it and needs it.

Other comments made on the day IFR runs were, by the pilots flying under best visibility conditions, "would like to see with (more) weather," and by those experiencing the lowest cloud deck, "due to low ceiling and good visibility, not a real good evaluation." A pilot who flew under minimum conditions commented, "(with) ceiling 200 feet...with fog, this shortened system appeared too skimpy for a safe operation. All runs were on the centerline and glideslope; had both been significantly displaced a missed approach could have resulted." This contribution reminds us that the worst conditions benefit from a full guidance system.

Not that it is needed to complete a landing when the aircraft is in the groove all the way, but that flying raw information, or with a less than Category II ILS, wind displacements, or other conditions that force the pilot to hunt for his approach path, even a full length, full strength visual system is not too much.

Results using the 3,000-foot-long reduced element system for day IFR, then, were that the pilots stayed with the preset intensity steps, found guidance adequate except for height guidance, a known deficiency of approach and runway light systems, and, overall, found the test system to support approaches.

<u>2,400-Foot-Long System:</u> In day IFR conditions 11 questionnaires were produced. As with the longer system, no intensity changes were requested by the pilots, and again that result made the second question not applicable. The third question produced data similar to that obtained with the longer system. Votes were 11 to 0 saying that approach zone identification and directional information were given adequately by the combined system. Roll guidance was approved 10 to 1 with one voting "fair" and, again, height guidance received the poorer endorsement, 8 yeses, 2 nos, and 1 fair.

Ratings of the usefulness of the strobe lights came out 10 "very important" and 1 "nice to have." One pilot specified very important "applicable to precision minima," and nice to have " applicable to non-precision minima." This would seem to imply that the strobes are very important for IFR when that broad label is extended to its full dimensions. Steady burning lights were rated "very important" by the same 10 votes versus 1 "nice to have."

The key sixth question, "Did the system adequately support your operation...?" received a 10 yes and 1 no vote. The negative came with a 200-foot overcast and fog condition. The pilot commented "weather was little too low to evaluate runway 4," which is interpreted to mean that the VOR approach procedure and shortened, economy, visual-guidance system left him with marginal guidance overall.

Added comments were mostly complimentary to the system. One pilot said "under the weather conditions...I doubt that a safe operation could have been performed without the experimental lighting system. The strobes were the first positively identified lights on all runs...."

Another pilot stated "Although the ceiling was somewhat below (minimums), landings were made possible by use of the lighting system." Summarizing the results of his experience, another pilot said "Light system was adequate...for VOR minimums...for runway 4, but is not adequate for lower minimums. System is too short for less than 1 mile (visibility), unless ILS type approach accomplished...." Both of the additional comments were simply favorable. One pilot said "...the lights were adequate." Another wrote "Aircraft broke out at 300 feet and strobes provided good guidance and identification. For marginal weather conditions this system would make a great difference in safety."

The results for the 2,400-foot system in day IFR are virtually indistinguishable from the parallel conditions with the 3,000-foot system. Both were accepted with the preset intensity steps. Principal elements of the MALSR were rated very important, and the system was voted adequate to support the operation.

Night IFR

3,000-Foot-Long System: In night IFR conditions, 9 series of approaches by seven pilots were made in the Gulfstream, Convair 580, and Convair 880 aircraft. Weather was poor in all cases with ceiling reported from 100 to 300 feet and visibility from 1/2 to 1 mile with rain and fog.

As with day IFR flights, the pilots did not request any changes in intensity steps for the runway edge lights or the strobe lights. Unlike the day condition, one-third of all the night IFR runs did result in a request for a change in the steady burning light stations in the ALS. The requested change was from step 3, the preselected standard, to step 2, the next dimmer step. One of the three pilots who requested the change said it was no improvement, i.e., "Lights were adequate but (were) more effective on step 3 for this visibility." Hence, only two pilots requested a reduction in steady burning light intensity and then judged the reduction beneficial. One of the two commented that, "Approach lights at step 2 seemed to be about the same intensity as runway lights."

Ratings of the guidance given by the combined system were positive in all cases with the single exception of adequacy of height guidance, where a single pilot rated guidance not adequate.

Night IFR produced nearly duplicate results, compared to day IFR, with respect to the rating of usefulness of strobe lights and steady burning lights. The combined questions produced 16 ratings of "very important" versus only 2 of "nice to have." No pilot rated either central element "unnecessary."

The general question produced a positive vote, 9 to 0, that the system adequately supported the operation.

Appended comments were strongly favorable to the system, with one exception, that still is not really unfavorable. That comment stated that the pilot had to stay on instruments because of the low ceiling (200 feet), but went on to say "... the copilot observing out the front found the entire system adequate." The other comments were: "Almost as effective under 300 feet/1/2-mile conditions as the full system," "very favorably impressed with system under these conditions," and finally, "most acceptable."

Night IFR weather, then, confirmed the adequacy of the 3,000-foot-long economy system. All lights were turned down from the day steps, of course, edge lights going from step 5 to step 3, MALS from step 5 to step 4, and RAILS from step 3 to step 2. These settings appeared adequate.

2,400-Foot-Long System: Additional night IFR flights on the shorter system resulted in nine more questionnaires. Generally, the weather was improved by comparison to the night IFR approaches to runway 13, the ceiling being as low as 300 feet, but visibility ranging upward from 1 1/2 mile in rain.

A number of changes in intensity were requested. One group of pilots began their approaches under what appeared to be VFR conditions, with the systems set at night VFR settings. Weather conditions deteriorated, and subsequently the flight was reclassified as IFR. The first of these pilots asked that all three elements, runway edge lights, steady burning lights, and strobes be reset to the night IFR settings and found the changes resulted in improvement. Particularly it was mentioned that a higher setting made the strobes more prominent and more effective. Three other pilots who flew that evening requested a total of four changes among them, and in each case they reported improved guidance with the greater intensities. Comments included the point that, initially, at night VFR

settings, the steady burning lights could be seen long before the strobes were picked up. At the next higher setting, which was the regular IFR setting, the strobes were seen at the same range as the MALS.

This set of nine questionnaires generally went along with the former set in rating the guidance of the combined system adequate. The divisions were 9-0 on approach zone identification, and 8-1 on the next two aspects, directional information and roll guidance. Height guidance, as before, got a lower approval, 7-2.

The consensus of the pilot ratings on usefulness on the strobe lights and steady burning lights was favorable. Six said strobes were "very important," one said "nice to have," and the remaining two pilots marked "nice to have" with the added comment of "at the higher setting." The only "unnecessary" ratings were by these same two pilots with the added comment "at the lower setting." This means that the higher setting was needed to give sufficient range, a point already made in comments on the first two questions. Steady burning lights were rated very important by seven pilots and nice to have by two.

On the general question, did the system adequately support your operation, eight said yes and one said no. This individual commented that he could not see because rain on the windshield was not properly cleared. Obviously, no visual guidance system will support operations without reasonable visibility through the windshield. Hence, we may conclude that night IFR with the 2,400-foot system was generally satisfactory, as it had been with the 3,000-foot system.

Night VFR

3,000-Foot-Long System: Night VFR conditions prevailed for the completion of 17 questionnaires with the full length MALSR. Reported conditions ranged from 600-foot ceiling, 2 1/2 miles visibility, rapidly improving, to CAVU. Only one pilot requested a change in runway edge light intensity setting, and this was a special case. On the night in question, flights began with IFR settings, but rapidly improving weather made the IFR settings too bright. All three systems were switched to VFR settings which "...provided an adequate and comfortable operation." Hence, this pilot actually endorsed the settings which were appropriate to the class of flight, that having changed after the start.

In contrast, nine pilots requested changes in the steady burning settings, and seven requested changes for the strobe lights. There is some uncertainty in one case, but all requests for changes in steady burning elements appear to have been requests for a lower setting. The strobes, on the other hand, were always changed to a higher setting. The goals of the pilots were long range identification of the approach zone from the stronger strobes and compatibility of elements. Pilots looking at lowered steady burning settings reported an improvement in compatibility, but most of those looking at increased settings on the strobes reported that the change did not actually help.

Guidance given by the combined system was rated adequate for approach zone identification (16-0), directional information (17-0), roll guidance (17-0), and height guidance (13-4). Usefulness of the strobes was rated "nice to have" on 12 questionnaires, "unnecessary" on 1, and "very important" on 4. Comments included "nice to have in clear visibility (but) very important for reduced visibility," "very important... where more surface lights are in or near the approach zone," "(would be very important at) strange airport," and "nice to have for straight-in approach, very important for circling approach." Usefulness of the steady burning lights was rated "nice to have" by 15 and "very important" by only 2. This outcome is different from that obtained after IFR flights and stems, no doubt, from the fact that in VFR conditions the runway is in sight during the approach. This makes a steady burning approach light system more a help than a necessity.

The comprehensive question, "did the system adequately support your operation... ?" was answered yes 17 times. MALSR was considered clearly adequate for VFR. Added comments were fewer in this better weather series. A representative item was "Not really required for this perfect weather condition." Another pilot summed up by writing, "System looks good for VFR."

2,400-Foot-Long System: Night VFR prevailed for 16 series of approaches to the shortened system. None of the 16 requested a change in runway edge light intensity setting, confirming the finding on the longer system that the predetermined setting is satisfactory in night VFR. There were three requests for a lower intensity on the steady burning lights, but such a reduction could not be made and was not evaluated on the next item. The strobe light intensity was, like the runway edge setting, accepted by all pilots.

All 16 questionnaires showed "yes" for all four parts of the third question, guidance being rated adequate on all counts.

Usefulness of the strobe lights was rated "nice to have" by nine; "unnecessary" by four and "very important" by only three. Usefulness of the steady burning lights produced an even division, eight rated "nice to have" and eight rated "very important." Alongside the nice to have marks, several pilots added "for VFR." Another two marked nice to have but unnecessary. Our interpretation of these widely divided rankings is that most pilots desire strobe lights for approach zone identification and directional information but find these guidance factors not absolutely essential in clear weather, particularly at a familiar airport. Similarly, steady burning lights are a plus, but not an essential, under these favorable conditions.

The question asking "did the system adequately support your operation...?" received 16 "yes" marks with one pilot adding notes on three deficiencies. He found some edge lights weak, as if dirty, some steady burning lights poorly aimed, and strobe lights too short to be really useful. He found that the MALS alone gave sufficient alignment information. Overall, though, this pilot said "...the system is more than adequate."

Added comments in this good weather series were few. One pilot wrote "The overall system was extremely useful for this VFR operation." Another suggested cutting some trees that blocked some views. Another finished by writing "Overall the system is excellent." Two pilots reported that the overall system was somewhat bright in clear night conditions. A further test at a secondary airport with approach from 10 miles at 2,500 feet was recommended by another. His idea was that the importance of strobes would be evident where runway identification was more difficult.

These questionnaire answers and comments indicate that the 2,400-foot-long system attained, under night VFR conditions, a degree of pilot acceptance roughly equivalent to that of the full length MALSR.

INTERPRETATION

Pilot responses indicate that the MALS/RAILS combined system with preset intensity steps is fully adequate and provides satisfactory

guidance. The only weakness noted with frequency is in provision of height guidance, where a substantial minority of the pilots failed the system.

Shortening the length of the system from 3,000 feet to 2,400 feet did not detract materially from its usefulness. Intensity steps for sequence flashers proved a useful feature, and the preselected intensity steps on the various subsystems proved adequate.